

AN ADDITION
VNTO THE VSE
OF THE INSTRUMENT
CALLED THE CIRCLES OF
PROPORTION, For the Working
of *Nauticall Questions.*

Together with certaine necessary Consi-
derations and Advertisements touching
NAVIGATION.

All which, as also the former Rules concerning
this Instrument are to bee wrought not onely
Instrumentally, but with the penne, by Arith-
meticke, and the Canon of
Triangles.

Hereunto is also annexed the excellent Vse of two
Rulers for *Calculation.*

And is to follow after the 111 Page
of the first Part.

LONDON,
Printed by AVGVSTINE MATHEWES.
1633.

AN ADDITION
VINTO THE VASE

OF THE INVENT
CALLED THE ORGLES OF
P... ..
of

Together with certain necessary Con-
clusions and Advertisements touching
NAVIGATION.

All which, as also the former Rules concerning
the Invention, are to be kept in the
Instruments, but with this, that by Auth-
orities, and the Canon of
Churches.

The same is also to be kept in the
Library of the University.

And it is to follow after the 111 Page
of this Book.

Printed by AVOGASTINE MATHIAS
London,



OF NAVIGATION.

CHAP. I.

*Certaine generall Advertisements concerning the
use of this Instrument; together with the de-
scription of such Circles as are newly added
thereto, serving for Navigation.*



When I penned the rules which have been formerly set out to shew the use of this Instrument, I was carefull to doe it with as much plainenesse and perspicuity, as might be in a subject not as yet obvious to vulgar knowledge, so that any one but moderately exercised in Arithmeticke and Geometrie, might (as I conceived) apprehend the workes and practices taught therein. But being since certified that some few difficulties seeme, or indeed rather are feared, to be in the manner of the delivery of those Rules: I thought it would not bee impertinent, and alien from this present purpose, if in the very beginning I shall endeavour to explaine such doubts, for the satisfaction of any that shall sticke thereat.

*The first part
of this Chapter.*

The scruples, which chiefly seeme to cause their
"difficultie, are these two: First, that the parts or fra-

“tions are not set downe with their Numerator and
 “Denominator, as is usually done; but are contained
 “with the whole Numbers, as it were in one summe,
 “with a small rectangular line only between them to se-
 “parate the parts from the Integers. And secondly, most
 “of the examples are not wrought at large, but the sum-
 “marie and finall resolution thereof briefly intimated.
 The former of which two scruples ariseth from the ig-
 norance of the true nature and manner of Decimall fra-
 ctions: and the latter, from want of rightly conside-
 ring the Rules, whereby the value of the number
 emergent or found out by proportion, and other A-
 rithmetically operations, is estimated: which are those
 that are delivered in the second and fifth Chapters of
 the first part of that booke.

That wee may the better conceive the nature of *De-
 cimal fractions*, let us imagine a line either straight or
 circular, of any length, bee it a foot, or a yard, or one
 degree, or many; or else an houre, or a day, or any o-
 ther continuity. This being considered in it selfe in-
 tire and undivided is an Vnite or one whole thing of
 that kind, as one foot, one degree, one houre, &c.
 Then imagine that Vnite or whole to bee divided
 to 10 equall parts, that whole shall bee 10. Again
 imagine every one of those tenth partes to bee sub-
 divided into 10: the whole shall bee 100, and each
 first division shall bee 10: and these second divi-
 sions shall bee hundreth partes. Thirdly, imagine
 every one of those hundreth partes subdivided in-
 to 10: the whole shall bee 1000, and each first divi-
 sion shall bee 100: and each second division shall bee
 10: and these third divisions shall bee thousandth parts.
 And so proceeding in this Decimall subdivision, you
 may in your imagination divide the Vnite or whole
 into ten-thousandth parts, and hundred-thousandth parts,

and millioneth parts, and so infinitely. And so that segment which in the first division was 10, 20, 30, &c. shall in the second division bee 100, 200, 300, &c. and in the third division 1000, 2000, 3000, &c. As for example,

$$\frac{3}{30} \text{ is } \frac{30}{100} \text{ or } \frac{300}{1000} \text{ or } \frac{3000}{10000} : \text{ and } \frac{45}{100} \text{ is } \frac{450}{1000} \text{ or } \frac{4500}{10000} : \text{ and } \frac{374}{1000} \text{ is } \frac{3740}{10000} \text{ or } \frac{37400}{100000} : \&c.$$

Hence followeth that you may encrease the Numerator of any Decimall fraction by putting thereto as many cyphers or circles as you please without altering the quantity thereof, so that also you joyne so many cyphers to the Denominator.

Now therefore a *Decimall fraction* is that which hath for his Denominator the figure 1 with one or more circles after it, as 10, 100, 1000, &c. And seeing the use of the Denominator in a fraction is to shew into how many such parts the whole or Vnite is divided: if otherwise by any convenient signe the Denominator may easily and certainly bee knowne by the Numerator onely, it will bee a needeleffe labour still to set it downe.

The most fit and convenient signe to know the Denominator of a Decimall fraction is by a *separating Line*. For if the number mixed of integers and parts be written together in one ranke, with a small rectangular line drawne next after the Vnite place, cutting off the parts from the Integers: the number of figures or places in the parts so cut off shall shew how many circles or cyphers are to bee set after 1 in the Denominator.

tor. As for example, $3700\overset{\circ}{6}$ is all one with $3700\overset{\circ}{7}$, that is 3700 Vnits, and six tenth parts. Again $370\overset{\circ}{06}$ is all one with $370\overset{\circ}{100}$, because after the separating line follow two figures 06. Likewise $37\overset{\circ}{006}$ is all one with $37\overset{\circ}{1000}$, because three figures 006 follow the separating line. Also $3\overset{\circ}{7006}$ is all one with $3\overset{\circ}{70000}$. And $0\overset{\circ}{37006}$ is all one with $\overset{\circ}{37006}$, that is no unite at all, but that fraction only. And $0\overset{\circ}{037006}$ is all one with $\overset{\circ}{037006}$, because after the separating line are six places of figures 037006. By all which diversities of placing the separating line it is apparant that *the number of circles in the Denominator of any Decimall fraction must bee equall to the number of places of figures following the separating line.*

Wherefore though there be no Vnite, but that it be a pure fraction, yet *it will be convenient to note the Vnite place with a circle before the separating Line*; that so the value of the fraction, through the number of places therein may more plainly appeare.

And besides that the setting of Decimall parts thus in one line with the Integers, hath more concinnity and neatnesse with it, then either with a Denominator, or by noting (as some have done) with small figures the primes, seconds, thirds, and the rest. These fractions both mixt and pure are ready without any further reduction, for any Arithmetical operation.

For in *Addition* and *Subduction*, the numbers given, being fitted together by their separating lines, having the like places or degrees set under one another, each in their owne file, may be added or subducted in the very same manner as if they were all whole numbers.

And in *Multiplication* the numbers given being multiplied

tiplied one by the other, according to the usuall manner of whole numbers, the product found out shall have so many places of parts, as are in both the numbers multiplied.

And in *Division* the ordinary manner of whole numbers is to be used; onely remembering that every figure of the Quotient shall be of that degree, whereof that figure of the Dividend is, under which the Vnite place standeth in the finding out of it, is.

Thus have I with as much plainenesse and brevitie as possibly I could cleered *the first scruple*, by shewing the *the reason of Decimall fractions*.

The second conceived difficultie is for not setting downe at large the operation of most of the Examples, but onely of some few here and there.

It is true that in every worke I doe not say (as some have done) bring that hither, or remove this thither: But having first taught the manner of working proportions upon the Instrument, and also delivered proper rules for particular questions, and wrought at the full summe of the hardest, I would not in every Example shew the like punctuallnesse, that neither I might blunt the edge and industrie of the ingenious Practicer with too much easinesse, nor the Booke grow to an enormous bulke and greatnesse.

That therefore the studious Reader may not need such verbosity and tedious instructions, he is to be advised oftentimes (and that attentively) to peruse the first chapter of the first part, where the *description and use of the severall circles* are declared: and also the second Chapter concerning the *working of proportions*,
and

and of *Multiplication and Division*: and therein those *four* Considerations, or Rules for finding out the true value of the fourth or emergent number sought for: And thereto the fifth Chapter of the *quadrating and Cubing of numbers*. For in assigning a true quantitie unto the Emergent number lyeth the greatest difficultie of this operation, especially if the worke bee in the fourth Circle.

In *Signes and Tangents* it is not altogether so hard, because all the revolutions or circuits of both are actually set downe in severall Circles.

The *Signes* have two Circles, which in this new addisament for Navigation are these; The *tenth Circle* from about 35 minutes, unto 6 Degrees; and the *First* from 6 Degrees, to 90, the end of the Quadrant.

The *Tangents* have foure Circles: namely the *Ninth* from about 35 minutes to 6 Degrees. The *Second* from 6 Degrees to 45. The *Third* from 45 Degrees to 84. And the *Eighth* from 84 Degrees till about 89 Degr. and 25 minutes.

But the *fourth Circle* being actually but one, dothe potentially containe all Degrees and places both of Integers and Decimall parts. For the nine figures written in the spaces may signify unikes, or tennes, or hundreds, &c. or else tenth parts, or hundreth parts, or thousandth parts, &c.

If any number be to be constituted upon the *fourth Circle* of the Instrument, take evermore one of those nine figures in the spaces for the first significant figure of that number: and among the subdivisions thereof reckon the true poynt or place of the number proposed.

As.

As if 2 were proposed: seeke the figure 3 in the spaces, & upon that line set one arme of the Index. Again if 375 be proposed: seeke the first figure 3 in the spaces: and in the subdivisions from 3 towards 4 account 75: and at the end thereof set one arme of the Index. Likewise if 1092 be proposed: because the two Circles are not significant, seeke the figure 9 in the spaces: and in the greater divisions thereof from 9 towards 1 account 2, and there set one arme of the Index.

If any *ratio* be proposed to be taken on the Instrument: set the two armes of the Index upon the two termes of the ratio found out, as was even now taught. Then consider the distance or arch betweene those two termes, counting from the place of the Antecedent to the place of the consequent forward, or according to the order of the figures, if the antecedent terme be lesse then the consequent: Or else backward, contrary to the order of the figures, if the antecedent be greater.

This distance or arch betweene the places of the two termes in the Instrument (which is also the aperture of the armes of the Index) I may fitly call the *Instrumentall difference*: but it is not evermore the *reall* or *true difference*: which also is most needefull to be knowne. The rules whereof are these three.

First, if either the numbers given be of the same degree: Or if they differ but one degree, and the *line of the Radius* fall betweene the places of the two termes in the Instrument: the *Instrumentall difference* shall also be the *true and reall*.

Secondly, if the numbers given be not of the same degree, and the *line of the Radius* fall not betweene
 B the

the places of the two termes in the Instrument: looke how many degrees the numbers differ one from the other, so many whole circuits of the *fourth Circle* shall bee added to the *Instrumentall difference* to make the *reall or true difference*.

Thirdly, if the numbers given be not of the same degree, and the *line of the Radius* doth fall betweene the places of the two termes in the Instrument: looke how many degrees the numbers differ, so many whole circuits, wanting one, of the *fourth Circle* shall be added to the *Instrumentall difference* to make the *reall*.

As in example: If the *ratio* of 375 to 2 be proposed: the same being taken upon the Instrument; the *true difference* betweene them, over and above the arch or angle of aperture, shall bee two whole circuits, by the second rule. And if the *ratio* of 375 to 0, 92 be proposed: the same being taken upon the Instrument; the *true difference* betweene them, over and above the arch or angle of aperture, shall, by the third rule bee but three whole circuits, (although the termes differ foure degrees) because the *line of the Radius* falleth within that arch, reckoning it from the antecedent arme to the consequent backward.

Againe, the antecedent terme of any *ratio* being given, together with the *reall or true difference* (that is both the due aperture of the Index, and also the number of circuits) betweene the termes, and whether of the two bee the greater: it is also needefull to know how to estimate the consequent terme. The rules whereof are these two.

Fourthly, if the *true difference* bee lesse then one circuit, and the *line of the Radius* fall not betweene the places

places of the two termes; the numbers are both of the same degree. But if the *line of the Radius* fall between them they differ one degree.

Fiftly, if the true difference containe one or more circuits, and the *line of the Radius* fall not betweene the places of the two termes; the numbers differ so many degrees as there are whole circuits. But if the *line of the Radius* fall betweene them they differ one degree more then there are whole circuits.

As in example: If the *ratio* of 375 to 2 be proposed: and also another antecedent $0^{\circ}29'$: unto which a proportionall consequent is required to be sought. Because the *true difference* of $0^{\circ}29'$ unto his consequent in the Instrument is equall to the *true difference* of 375 to 2, that is two whole circuits more then the aperture: and the antecedent $0^{\circ}29'$ is greater then the consequent sought for: set the antecedent arme of the Index upon $0^{\circ}29'$, and the consequent arme reckoning backward, at the same aperture, will cut 49+. But of what vallue or degree this fourth number is, is yet uncertaine. Now forasmuch as the *reall difference* betweene the termes of the *ratio* proposed is two whole circles above the aperture, as was shewed in the former example after the third rule; And in this present position of the Index the *line of the Radius* falleth not between the armes: the *difference of degrees* shall also bee two, by the fifth rule. Wherefore the first figure of 49+ shall bee two whole degrees backward from the first significant figure of $0^{\circ}29'$ that is $0^{\circ}00'49'$ (*viz*) somewhat better then 49 hundred thousand parts.

Again, if the *ratio* of 375 to $0^{\circ}29'$ be proposed: and also another antecedent 2, unto which a proportionall consequent is required to bee sought. Because the *true*

differens of 2 unto his consequent in the Instrument, is equall to the true difference of 375 to 0⁹²: and the antecedent 2 is greater then the consequent sought for. Set the antecedent arme of the Index upon 2, and the consequent arme reckoning backward at the same aperture will cut 49+ as before. Now forasmuch as the *reall difference* betweene the termes proposed is three whole circuits above the aperture of the Index, as was shewed in the latter example after the third rule. And in this present position of the Index the *line of the Radius* faileth betweene the armes the difference of degrees shall be one more then three, that is foure by the *fifth rule*; wherefore the first figure of 49+ shall bee foure whole degrees backward from 2, that is 0⁹⁰49+. I will conclude this part, with a summary recapitulation of all the former rules into these two branches.

The termes of a ratio being proposed, to find the *reall or true difference* betweene their places in the fourth circle of the instrument. I. If either the numbers given be of the same degree: or else differ but one degree, the line of 1 falling betweene them: they differ lesse then a circuit. II. If the numbers bee not of the same degree: they differ so many whole circuits as they doe degrees. But yet if the line of 1 fall betweene them: they differ one circuit lesse.

The antecedent terme of a ratio being given, together with the *reall or true difference* of the termes in the Instrument: to find out the consequent terme. I. If the *reall difference* be lesse then one circuit, and the line of 1 fall not betweene the places of the two termes: the numbers are both of the same degree. But if the line of 1 fall betweene the places: they differ one degree. II. If the *reall difference* containe one or more circuits: the numbers differ so many degrees as there are whole circuits. But if
the

the line of λ fall betweene the places : they differ one degree more.

Thus have I with as much perspicuousnesse as I am able, explained the generall rules of working by this Instrument, which have beene delivered in the *first*, *second*, and *fifth* Chapters of the *first part* : and exemplified the documents with as hard examples as any I could bethinke my selfe of. And now I suppose the solertious practizer will bee able easily to finde out a fourth proportionall unto any three numbers given, and certainly to estimate the value thereof: so that now he will not be troubled for want of working the Questions at large.

For the use of Navigation are added two circles, The second part the sixth and the seventh : and a small alteration in the of this Chapter. fifth. For the fifth circle is here divided also into 50 parts : and is conceived to have two circuits. The first circuit is unto 50 : The second circuit from 50 unto 100. Wherefore the figures are doubly noted : on the neerer side of the long lines of tenth divisions are set 10, 20, 30, 40, 50, for the first circuit : And on the further side of those lines are set 60, 70, 80, 90, for the second circuit. And the ten subdivisions in every one of those 50 parts are the Decimall parts thereof.

The *sixth* and *seventh* circles are divided into degrees: and every degree into ten parts, containing 6 minutes, or rather 10 hundredth parts a peece, The *sixth* circle hath the degrees unto $44\frac{1}{2}$: and the *seventh* circle hath from $44\frac{1}{2}$ unto 70. And these degrees serve for so many severall *Latitudes*, or *Elevations of the Pole*.

The manner of using these circles is double. First, *Two Latitudes being given in the same Hemisphere, that*

is both Northerne, or both Southerne, to find the Summe of all the Secants betweene them. Set one arme of the Index upon one Latitude and the other arme upon the other; then remove the arme that stood upon the lesser Latitude unto the line of the Radius: and the other arme with the same opening, shall in the fifth circle give the number of Secants betweene the two Latitudes proposed. As if the number of Secants betweene these two heights of the Pole $48^{\circ}13'$ and $56^{\circ}17'$ bee desired. Set one arme of the Index upon $48^{\circ}13'$ and the other arme upon $56^{\circ}17'$: then remove that arme that stood upon $48^{\circ}13'$ unto the line of the Radius: and the other arme with the same opening, shall in the fifth circle give $131^{\circ}53'$, the number of Secants betweene the two Latitudes proposed.

Secondly, The Summe of all the Secants between two Latitudes in the same Hemisphere being given, together with one of the Latitudes, to find the other Latitude. Set one arme of the Index on the line of the Radius, and open the other arme unto the Summe of Secants given (in the fifth circle): then remove the arme that stood on the line of the Radius to the Latitude given, if it be the lesser: or if the Latitude given be the greater, remove that arme that stood at the end of the Summe of the Secants, unto that greater Latitude: and the other arme at the same opening shall give the other Latitude. As if there be given $131^{\circ}53'$ the Summe of Secants from the Latitude of $48^{\circ}13'$ to the Pole-ward: Set one of the armes of the Index on the line of the Radius, and the other arme at $131^{\circ}53'$ in the fifth circle. Then remove the arme that stood at the line of the Radius, unto the Latitude $48^{\circ}13'$: and the other arme, at the same opening shall point to $56^{\circ}17'$ the degrees of the other Latitude sought for. Again, if the same Summe of Secants $131^{\circ}53'$, with the greater Latitude $56^{\circ}17'$ degrees, be given: set one of the armes of the Index on the line of the Radius,
and

and the other arme at $131^{\circ}53$ in the fifth circle. Then remove the arme that stood at $131^{\circ}53$, unto $56^{\circ}7$ deg: the greater Latitude, and the other arme, at the same opening shall cut $48^{\circ}3$ deg: which is the lesser Latitude sought for.

And if the two Latitudes be in the severall Hemispheres, that is one Northerne and the other Southerne, the manner of working differeth in effect but little from the former. As if the summe of the Secants betweene these two heights of the Pole, viz. 65 on the North side of the Equinoctiall, and $131^{\circ}4$ on the South side bee desired. Set one arme of the Index on the line of the Radius, and the other arme on either of the Latitudes given, suppose on 65 . Then bring that arme on 65 unto the line of the Radius: and where the other arme, at that opening, chanceth to light, there hold it fast: and open the arme that standeth on the line of the Radius, unto the other Latitude $131^{\circ}4$. Afterward bring the arme that stood on the former Latitude 65 unto the line of the Radius, and the other arme, at the same opening, shall in the fifth circle cut $20^{\circ}37$, the summe of Secants sought for.

Lastly, the summe of all the Secants betweene two Latitudes, of which one is on the North side of the Equinoctiall, and the other on the South side, being given; together with one of the Latitudes, to find the other Latitude: As if the summe of the Secants be $20^{\circ}37$ and the Latitude degr: 65 . Set one of the armes of the Index at the line of the radius: & open the other arme unto $20^{\circ}37$ in the fifth circle: & keeping the same aperture, bring the arme that stood on the line of the radius unto the latitude 65 : and the other arme shall shew $131^{\circ}4$, the other Latitude sought for.

Or else peradventure you may more easily find out the

Cancelled - see after errata.

summe

summe of the Secants betweene any two Latitudes given, thus: Set the edge of the Index upon one of the Latitudes: and looke what division it cutteth in the fifth circle: keepe it in minde. Againe, set the edge of the Index upon one of the Latitudes: and looke what division it cutteth in the fifth circle: keepe that in mind also. These two numbers kept in mind are the summes of the Secants for the two Latitudes given: And are to be subduſted one out of the other, if the Latitudes are both in the ſame Hemisphere: or elſe to be added together, if the Latitudes are in diuerſe Hemispheres.

Alſo in like manner, The ſumme of the Secants and one of the Latitudes being given, you may find out the other Latitude thus: Set the edge of the Index upon the Latitude given; and looke what division it cutteth in the fifth circle. To this number adde the ſumme of the Secants, if the leſſer of the two Latitudes be given: Or elſe out of it ſubduct the ſumme of the Secants, if the greater of the two Latitudes be given. But if the two Latitudes are in the contrary Hemispheres, the number found in the fifth circle is to be ſubduſted out of the ſumme of the Secants. And ſo ſhall you have the other Latitude.

CHAP.

CHAP. II.

*Of the Latitude, and Longitude of places in
generall: and of keeping the account of
time at Sea.*



He care and skill of the perfect Sea-man is to guide the ship at sea unto any port that shal be desired: which cannot be done unlesse he bee able to find out in in what place the ship is at any time.

The place of the ship at sea is estimated and understood by comparing it with any knowne place: that is how much the same is situated from the place, where the Ship is, either toward the North or South, which is called the difference of Latitude: or else toward the East or West, which is called the difference of Longitude. For it being once knowne how farre any place upon the Globe of the earth is wide of the *Aequinoctiall* unto either Pole: and also how farre the Meridian of the same is distant from the Meridian of any knowne place: the true situation thereof is said to be had.

The Latitude or distance of the place wherein the Ship is from the *Aequinoctiall* (which is all one with the height of the Pole there) is taken by observation of the Meridionall altitude, either of the *Sunne* by day, or of any *Starre* by night: as is not unknowne to almost every common Mariner: Or also by the 47 proposition of the 12 Chapter of the first Part. And therefore being so vulgarly knowne, and taught of most that write of Navigation, I shall not need to spend time about it:

C

Especi-

Especially my intent here being to teach the use of my Instrument only, in tracing the Ships course.

The *Longitude* of the place wherein the Ship is, that is the Easterly or Westerly distance of the Ship from the place whence the Voyage began, is the difficultie, and *Master-piece of Nauticall science*: Which hath set on worke the wits and inventions of many men, proceeding therein on diverse grounds.

For some have laboured to find the reason thereof by the variation of the *Magneticall needle*, supposing certaine Poles or points, unto which the ends of the needle doth in all places exactly respect. But besides that the *Meridian is difficultly to be had* with sufficient preciseness, especially at Sea, where the chiefest use of *Longitude is*: the concept is only imaginary, without the warrant of any naturall principle.

Some considering the swiftnesse of the motion of the *Moone*, which is every day above 13 degrees, have supposed that either by the true place of the *Moone*, to be observed by exact Instruments; or else by the moment of the *Moones comming into the Meridian*, the *Longitude* might bee obtained. But neither the true motion of the *Moone is so exactly knowne*, nor observation can at Sea bee so precisely made, that any certaine truth in so subtil a businessse may be argued thereby.

Some have thought to observe the *Longitude* with automata or artificiall motions of long continuance: but not without great error and hallucination.

Some by *Sand-glasses*, or *Water-glasses*: but both obnoxious to the diverse alterations and temperatures of the aire and climate wherein they are, especially that of
sand.

sand. The other by *water is more probable*: wherein I should, in my judgement, preferre some *chymicall spirit* or liquor: because it is not so subject to the impression of the *aire*. And that there should be *three glasses* used, one to runne, and two to receive successively: That which runneth to be open above, to poure in the liquor, and to let in the *aire*, that the issue of the water be not hindred for want of *aire* to supply the vacuities: The receivers to be cylindricall, with markes set on the outside distinguishing houres and parts: and that there bee two of them, that when the liquor is come to the just height, another may instantly bee substituted, without losse of any liquor or time. This manner of observing the time is, in my opinion, the most likely of any that I know in use to conduce to the attaining of the *difference of Longitudes* of places. For by this meanes the *true time* in the place where the account beganne being knowne; and the *time by observation* of the sunne or some Starre in the place, whither the Ship is come, being found; the *difference of those times* resolved into degrees of the *Aequinoctiall* will shew the *difference of Longitude* betweene the place of beginning the account, and the place where the Ship is, *Eastward*, if the excessse be of the time in the former place: or *Westward*, if the excessse be of the time in the present place of the Ship.

And in this manner of *keeping the reckoning of Longitude* it will bee expedient to make as *frequent observations* as the serenity of the skye will permit: that thereby your account may the rather bee freed from such subreptitious errors, which else will bee very incident.

This or any such way of keeping the time, which shall by experience bee found most certaine (untill it shall please God to open a more naturall and proper way

way for the discovery of *Longitude*) I would advise were carefully, and with a kind as it were of religious diligence practised in all, specially long voyages; and that in computing and tracing the *course of the Ship* by the *Compass* and *log-line*, it also together with the *Latitude* observed be discreetly called into consultation.

CHAP. III.

Of the Mariners Compass, and Rumbes or points thereof: and of finding the circuit of the earth in miles.



Here be foure things therefore whereof a Seaman should be most carefull & circumspect, that he may happily with prosperous success and a good conscience performe his intended voyage: First the angle of inclination with the *Meridian*, on which the *Ship* maketh her course: which angle is directed by the *Compass*: and is commonly called the *Rumbe* or *poyn*t of the *Compass*. For the ordinary Mariners (by a rude and grosse division of the *Horizon* into 32 parts) observe 32 points, whereof foure are cardinall; other foure halfe points; eight are quarter points; and sixteene are by points. Others more curiously divide each point into foure parts making in all 128, which they denominate by a quarter, an halfe, and three quarters of a point. A point containeth degr: $11\frac{1}{4}$, that is degr: 11, min: 15, or degr: $11\frac{1}{2}$; and a quarter of a point therefore is degr: $2\frac{1}{8}$, that is degr: 2, min: 48, or degr: $2\frac{1}{4}$. By the continuall addition of which number this table of *Rumbes* ensuing is composed.

THE TABLE OF RVMBES. 19

Rumbs.	Rumbs.	Grad.	Gr. min.	Rumbs.	Rumbs.
NORTH.		The Meridian Line,		SOUTH.	
		21 ⁸ 12 ⁵	2 48 ¹⁷ 5		
		5 ⁶ 2 ⁵	5 37 ¹⁵		
		81 ⁴ 37 ⁵	8 26 ²⁵		
<u>NbE</u>	<u>NbW</u>	11 ¹ 2 ⁵	11 15	<u>SwW</u>	<u>SeE</u>
		14 ⁰ 62 ⁵	14 37 ⁵		
		16 ¹ 82 ⁵	16 52 ¹⁵		
<u>NNbE</u>	<u>NNW</u>	19 ⁰ 87 ⁵	19 41 ²⁵	<u>SSW</u>	<u>SSE</u>
		22 ¹ 5	22 30		
		25 ¹ 31 ²⁵	25 18 ⁷⁵		
		28 ¹ 2 ⁵	28 7 ¹⁵		
<u>NEbN</u>	<u>NwbN</u>	30 ¹ 93 ⁷⁵	30 56 ²⁵	<u>SwbS</u>	<u>SebS</u>
		33 ¹ 7 ⁵	33 45		
		36 ¹ 56 ²⁵	36 33 ⁷⁵		
		39 ¹ 37 ⁵	39 22 ¹⁵		
<u>NE</u>	<u>NW</u>	42 ¹ 18 ⁷⁵	42 11 ²⁵	<u>SW</u>	<u>SE</u>
		45	45 00		
		47 ¹ 12 ⁵	47 48 ⁷⁵		
		50 ¹ 62 ⁵	50 37 ¹⁵		
<u>NEbE</u>	<u>NwbW</u>	53 ¹ 43 ⁷⁵	53 26 ²⁵	<u>SwbW</u>	<u>SebE</u>
		56 ¹ 2 ⁵	56 15		
		59 ⁰ 62 ⁵	59 37 ⁵		
		61 ¹ 87 ⁵	61 52 ¹⁵		
<u>ENE</u>	<u>WNW</u>	64 ¹ 68 ⁷⁵	64 41 ²⁵	<u>WSW</u>	<u>ESE</u>
		67 ¹ 5	67 30		
		70 ¹ 31 ²⁵	70 18 ⁷⁵		
		73 ¹ 2 ⁵	73 7 ¹⁵		
<u>EbN</u>	<u>WbN</u>	75 ¹ 94 ⁷⁵	75 56 ²⁵	<u>WbS</u>	<u>EbS</u>
		78 ¹ 7 ⁵	78 45		
		81 ¹ 56 ²⁵	81 33 ⁷⁵		
		84 ¹ 37 ⁵	84 22 ¹⁵		
<u>East</u>	<u>West</u>	87 ¹ 18 ⁷⁵	87 11 ²⁵	<u>West</u>	<u>East</u>
		90	90 00		

The second is the *measure of the Ships way on the Rumbe or point*, which is ordinarily reckoned in *miles*; supposing a *mile* on earth to answer to a *minute of a degree*; and that *60 miles on a great circle* give the difference of one whole degree. But I rather reckon the way of the Ship in *hundredth parts of a degree*, and have framed my rules of Navigation thereto: because this hath a more easy and convenient calculation then that by *sexagesime parts*: and as I beleeve (for so I would have it) will hereafter grow into publike use. This *measure or quantity of the Ships way* is found by the *Logg-line and minuse-glasse*.

The other two are, The *observation of Latitude as oft as it may be* for the weather: and the *keeping of time*: Of both which I spake sufficient for my purpose in the former chapter. The two former, that is the *Rumbe and way of the Ship*, more properly fall within my present consideration. For these are the *continuell companions and faithfull guides of the Sea-man*, which must direct him still in shaping his course: unto these therefore hee must applie his studie, and acquaint himselve most familiarly with them.

And first for his *compassse* he must be carefull or rather scrupulous that it be *exactly made*, and not bungled up, as those usually are, which are made for sale: but that they be framed by some skillfull and conscionable Artificer. The manifold cautions which are fit to bee had therein, are very gravely advertised by that reverend *Divine and learned Mathematician Master William Barlow* in his *Navigators supply* neere the beginning.

And as he is in the *making of his compassse* to shew his care, so specially in the *using thereof* he must exercise all *industrie and diligence*, that the *course be steered aright*,
and

and kept to the *just point or Rumb* : and not to commit his owne and all his companies safety, and the good successe of the voyage to the *negligence of a loose and idle Steeresman* : whereby it cannot be but that the account of the Ship shall be much confounded, and made uncertaine.

Againe for *measuring of the quantity of the ships way*, It must first be knowne how many English feet of 12 inches to the foot, answer to one degree of great circle upon the earth. For if this be enormously mistaken, it cannot bee that the computation of the ships course shall agree with the observations : but must needs make a maine difference, to the amazement of the Sea-man, and the casting of the whole Ship and company into unforeseene dangers.

Now an *English mile by statute* is the length of 8 furlongs : and every furlong is 40 perches : and a perch is feet 16 $\frac{1}{2}$: so that by this reckoning a mile containeth 5280 feet in length : though it be usually taken, or rather mistaken, that 60 of such miles make a degree (which would bee very strange, that our English mile drawne from Barley cornes should so happily fall out to answer to one minute) yet the truth is that above 66 of our miles answer to a degree, as by the observations of the most diligent enquirers is found out : so that in voyding of every ten degrees above one degree is lost : which is a maine enormity. But of this enquirie it will not bee amisse from our purpose if we shall a little discou. se.

Diverse wayes by diverse Artists have beene practised for finding out the true compasse of the earth : And I know not whether any have given full satisfaction therein : but either the grounds they have wrought on have beene uncertaine ; or the distances of the places of observation too short ; or the diligence of the practiser to bee suspected. That way which is by the height of an hill, and a tangens
line

line from thence to the superficies of the sea, is rather a phantasie, then a thing of actuall performance. For neither the perpendicular height of the hill above the leuell of the water can with any certainty bee obtained: nor such a tangent line by reason of the refraction of the vapours continually rising out of the sea can be estimated.

But it would for the performance hereof be an excellent worke, if the height of the Pole at two townes of this Land, distant North-ward one from the other some scores, or rather hundreds of miles, being with Instruments of sufficient magniude by some learned Artists exactly observed: there were also imployed certaine skilfull Surveyors (such as are indeed lovers of art and truth) to take the true distances and positions from place to place betweene the said townes. Which survey I could wish were made with good plaine tables, and with the same scale, which should not belisse then a foot by standard for 10 miles and that these measures of a foot according to a standard were all made in brasle by the same Workman: and their chaines exactly fitted thereto: and that the measure bee taken not along the High-wayes, but by side stations where Steeples and other places eminent and of note may bee seene. If the two townes of the observations were London and Edenborough, it would be precisenesse sufficient: nay if they were but London and Cambridge, it would yield a greater certainty then any that I know hath yet beene used. This I say were an excellent work, and worthy the heroicall magnificence of some great man: and yet not of any very chargeable performance: but it would bring a marvellous light and furtherance to Navigation and unto all Astronomic.

In the meane time till it shall please God to stirre up some truly noble spirit for the effecting thereof, I will make bold to propose a way, which any ingenious student, whose sight both of his eyes and understanding is quicke

quicke and perspicacious, may himselfe privately with much facility practise: the reason whereof consisteth upon these three principles.

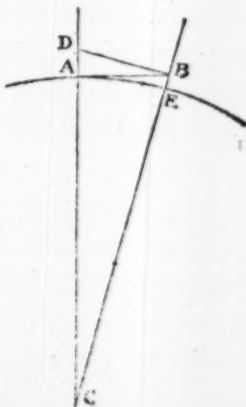
The I. is, that if with a levelling Instrument set up in any place parallel to the Horizon a man take a true levell unto another place: the visuall line by which he levelled, shall be a tangent to such an arch of a great circle on the earth, as is contained betweene the station and the marke: Because that the visuall line, together with the two lines imagined, out of the center of the earth, doe include a right angled Triangle, having the right angle at the levell.

The II. is, that if the same Instrument be set just even with the former mark, and you levell backward to the former station, this last visuall line shall overshoot the former place of the Instrument: and shall inclose a new and greater right-angled triangle, having the right angle at the second station.

The III. is, that the former of the two visuall lines shall cut this latter and greater right-angled triangle into two right angled triangles like to it self and one like to the other: by

the 8 prop: of the 6 book of Euclide. As in the scheme, the center of the earth is C, the first place or station of the levelling instrument is A, and the visuall line thence is A B to the marke B, which is also the place of the Instrument in the second station, from whence the visuall line backward is B D, over-reaching the first place A. Here are 3 like right-angled triangles, namely the greatest C B D, cut into two other C A B, and B A D, with the line A B.

Wherefore A B. A D :: A C. A B: that is; as the distance



D

be-

between the two Stations (for by reason of the vast greatnesse of the earth, and the exceeding small distance betwene the two stations in comparison thereof, the visuall line AB shall be the same with the ground line AE) is to the over-shooting of the second line of levell: so is the Radius to the tangent of the arch AE, intercepted betwene the two stations. The quantity of which arch being sought out in the Canon of tangents, either in sexagesime or Decimall parts of a degree, say againe, As the same arch in sexagesime or Decimall parts of a degree is unto a degree in the like parts; so is the distance betwene the two stations in feet, to the number of feet answering to a degree upon the earth. As for example, suppose the distance between the two stations to be 528 feet, which is the tenth part of a mile: and that the second line of levell over-shooteth the former $\frac{18}{10000}$ of a foote: or 0.0138, which you shall finde will bee neere about the matter. Say,

528 . 0.0138 :: 100000,00 . 2,61 : the tangent of the arch Min, 0.02+

Say againe,

0.02+ . 60 :: 528 . 351120 ; the number of feet answering to a degree upon the earth.

Thus have I set downe the rule, and illustrated it with an example. But in the practise (by reason of the weaknesse of our sight, not able to discerne a thing distinctly at any great distance, we are constrained to take but short stations, whereby the over-shooting of the second line of levell above the first is but very small) there is required great precisenesse. For the performance whereof it will not bee amisse to set downe some directions, both concerning the Instrument, place, and time.

The levelling Instrument to be used in this worke, I would not have to bee either with a channell for water; nor

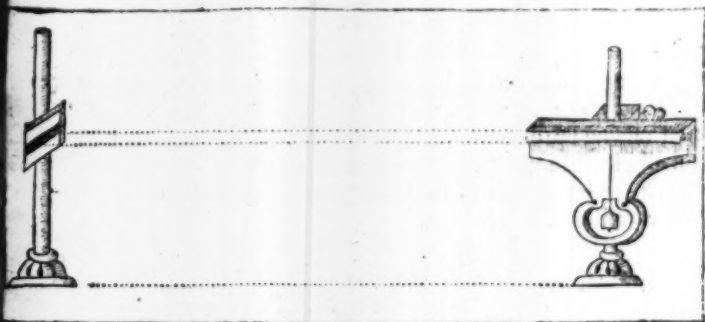
nor with sights. For the water, besides that it doth continually exhale vapours, hath a certaine tenacity, whereby to avoyd any drynesse neere to it, it will rather collect it selfe, and stand in a heape, then mixe with its enemy: and contrariwise very gladly diffuseth it selfe in pursuit of any moisture. And as for Sights, if the sight-hole be very small, it hindreth our seeing: if any whit large, it admitteth too many visive rayes; which dilating themselves cannot fixe on the true and individuall point of the object. But I would have it onely with a ledge, one inch thicke, and three inches broad: and so broad also I would have a blacke stroke to be in a square white board, for the marke to levell at, that having set the ledge of the Instrument by the plumb-line parallel to the Horizon in one station, you standing aloofe off, and guiding your eye along the two edges of the ledge, and your companion at the other station rayeing up or letting downe the marke-board, as you shall direct him, you may see the upper line of the blacke stroke levell with the upper edge, and the lower line levell with the lower edge.

The place for the tryall of this experiment, I would have to be a plaine field, wherein you are to have for your use ready measured out by the foot, directly East and West, such a distance, as you can discern distinctly thereat: which to a good and perfect sight may be 1000 feet, or to an indifferent sight 528 feet, which is the tenth part of a mile. And at both ends of that distance (which are to be your stations) the ground to be handsomely plained and beaten, for the more exact setting up of your Instruments thereon.

The time for making your observation I would have about Midsummer, in a seasonable, constant, drye, and calme weather: when, having set up your levelling Instrument in the Easterne station, you may take your first

levell about *eleven a clocke in the forenoone*. Which being done, you may remove your Instrument to the *Westerne station*, and about *one a clocke in the afternoone* (when the Sun is gone so farre past the Meridian) take your backe levell.

These are the most *necessary* and *accurate cautions* that I can devise : and all little enough for so curious and sub-
till an inquiry. I have also here set downe the *formas of the levelling Instrument and of the marke*.



CHAP. IIII.

The manner how to measure the Ships way ;
or how many degrees, and parts of a degree,
either centesimes, or sexagesimes, the Ship
moveth in one houre; or in any space of
time assigned. And also of certaine ne-
cessary reductions.



We shall therefore come neere the matter if
wee take miles $66\frac{1}{2}$, that is 349800 feete to
answer to a degree upon the earth.

Now because the measure of the Ships
motion or way is observed by the watch-glasse and Log-line:
let us for brevity sake call the number of seconds (whereof
there are 3600 in an houre) which the Watch-glasse run-
neth, by the letter G: and the number of feet vered in the
Logg-line while the glasse is running, by the letter F.
Which grounds being thus layed, wee may find out a
rule to know how many hundreth parts of a degree the Ship
sayleth in one houre; after this mannér.

Say G . F :: 3600 . $\frac{3600F}{G}$: so many feet gone in an houre

Say againe 349800 . 100 :: $\frac{3600F}{G}$. $\frac{360000F}{349800G}$:

Or by reduction into parts having the Denominator one

Unite $\frac{1092 F}{G}$: which are so many centesimes of a degree
gone in an houre.

Hence ariseth this generall rule for Centesimes.

As the number of seconds in the Watch-glasse, is
to the number of feet vered in the Log-line :

So is 11029 ,

to the number of hundreth parts of a degree,
which the Ship runneth in one whole houre.

But to know how many minutes of a degree the Ship
sayleth in one houre : Say againe

$349800 \cdot 60 :: \frac{3600F}{G} \cdot \frac{216000F}{349100G}$: Or by reduction

into parts having the Denominator one Vnite $\frac{0,6175F}{G}$:

which are so many sexagesimes of a degree gon in an houre.

Hence also ariseth this generall rule for sexagesimes.

As the number of seconds in the watch-glasse, is
to the number of feet vered in the Log-line :

So is $0,6175$,

to the number of minutes of a degree sayled in
one houre.

These two numbers 11029 and $0,6175$ (or whether of
them you meane to follow) being of most frequent, and
indeed continuall use, it were fit to note in the fourth
circle of your Instrument with some apparant marke :
that you may not be still searching them out, when you
have occasion to use either of them.

And after this very manner you may find a generall
rule for any other number of feet contained in a degree
upon earth, both for the Decimall parts of a degree, and
also for the Sexagesimes wherein onely the third
termes in every of the second proportions will bee
changed.

Because

Because the true finding out of the way, which the Ship maketh in an houre, estimated in the parts of a degree, is the maine ground and principle, by which the place of her being both for longitude and latitude is argued and computed: I will set downe the practice thereof at large in two Examples: the first for centesimes of a degree: and the second for sexagesimes:

Example I. Suppose the Watch-glasse to containe 40 sec: and that in the running out thereof the Ship hath gone 175 feete by the Log-line. The rule is, As 40. to 175: so is $1^{\circ}22'$, to the number of hundreth parts of a degree sought. Set therefore the antecedent arme of the Index on 40 in the fourth circle, taking the figured divisions 1, 2, 3, &c. for so many tens: and open the other arme unto 175, taking the same divisions for so many hundreds: the distance betweene the arme: will be above halfe that circle. Then remove the antecedent arme unto the third terme $1^{\circ}22'$, taking the same divisions for so many unites: and the consequent arme shall point at 450, which shall be 4 centesimes and a halfe, or 45 thousandth parts of a degree, (*viz*) degr: $0^{\circ}45'$, in the same circuit of that circle: because the distance from 40 to 175 outreacheth not the line of 1: Wherefore the Ship at that swiftnesse shall goe in an houre degr: $0^{\circ}45'$. Which in sexagesimes will be found to be Min: 27.

Example II. Suppose the same watch-glasse of 40 sec: and that in the running out thereof the Ship hath gone 512 feet. The rule is, As 40 is to 512: so is $0^{\circ}61'25''$, to the number of sexagesimes or minutes of a degree sought. Set therefore the antecedent arme at 40, and the other at 512: the distance betweene them exceedeth one whole circuit. Then remove the antecedent arme to the third terme $0^{\circ}61'25''$: and the consequent arme shall point out 7902: which because the distance exceeded

one

one circuit shall bee Min: $71^{\underline{902}}$. Which in centesimes would have beene degr: $01^{\underline{317}}$.

The proportion of the Ships sayling for one houre being thus given either in centesimes or sexagesimes of a degree: multiply the same by the whole time of the continuance at the same swiftnesse reckoned in houres and Decimall parts of houres: and the product shall give the whole way the Ship hath made, either in degrees or minutes accordingly. As for Example; If the Ship sayling after degr: $01^{\underline{045}}$ in an houre, continue so for Ho. 29, Min: 37, that is Ho: $291^{\underline{617}}$: Multiply $291^{\underline{617}}$ by $01^{\underline{045}}$, and the product shall bee degr: $113^{\underline{33}}$, the whole way that the Ship hath made. Or if the Ship for so long continuance hath sayled after Min: $21^{\underline{7}}$ in an houre: Multiply $291^{\underline{617}}$ by $21^{\underline{7}}$ and you shall have Min: $7199^{\underline{66}}$, which being diuided by 60, will give degr: $113^{\underline{33}}$, as before.

Now follow certaine reductions, which are of frequent use. I. To convert degrees or houres into Minutes, is to multiply them by 60. And to convert them into seconds, is to multiy them by 3600. And contrariwise.

II. To reduce minutes into degrees or houres, is to divide the minutes by 60. And to reduce seconds into degrees or houres, is to divide them by 3600.

III. To convert minutes of degrees or houres into centesimes or hundreth parts: Say, As 60, is to 100: so is the number of minutes, to the number of hundreth parts. And,

IIII. To reduce centesimes of degrees or houres into minutes: Say, As 100, is to 60: so is the number of centesimes or hundreth parts, to the number of minutes.

CHAP. V.

*The division of sayling into circular and spirall.
Two fundamentall theorems. Of sayling
by one of the foure Cardinall Rumbes: and
certaine Questions belonging thereto.*



HHe motion of the Ship upon a Rumb is either circular, or winding with a kind of spirall line. If the ship saile upon one of the foure cardinall points, it describeth a circle: which is either a great circle or lesser, according as the circle of the heavens is, under which it moveth. For if the Ship saileth directly North or South under some Meridian, or directly East or West under the Equinoctiall, it describeth by the motion thereof an arch of a great circle. But if it saile directly East or West wide of the Equinoctiall on either side, it describeth a lesser circle, according as the parallel in the heavens is, under which it moveth.

All great circles are equall one to another, and have equall degrees: but the parallels are greater or lesser one then another; and consequently have greater or lesser degrees, as every one is neerer or farther distant from the Equinoctiall. And because in computing the motion of the ship we shall have continuall occasion to speake of degrees both of the greater and lesser circles, let this be advertised, that as oft as I shall mention Inst Degrees, I understand the measure of so many degrees of a great circle; else speaking of lesser degrees, I call them proper degrees of such a parallel.

These two proportions following are the fundamen-
E tail

all Theoremes for the computation of the motion of the ship :
and are therefore faithfully to bee imprinted in our memory. The second is but the converse of the first :
and are so familiar, that they shall neede no demonstration.

Theor. I. As the *Radius*, is
to the sine of the complement of the parallel :
So is an arch of the *Æquinoctiall* in *Iust Degrees*,
to the number of *Iust Degrees* contained in a like
arch of the same parallel.

Theor. II. As the sine of the complement of the
parallel, is to the Radius : Or
As the Radius, is
to the secant of the parallel :
So is the number of *Iust Degrees* contained in an arch
of the same parallel,
to a like arch of the *Æquinoctiall*.

If a Ship saile under a *Meridian*, that is upon the
North or *South Rumb*, it varyeth not the *longitude* at
all : but onely changeth the *Latitude* : and that just so
much as the number of degrees it hath runne in that
whole time amounteth unto, which number is to be ad-
ded to the latitude of the place, where the account began,
if you have sayled from the *Æquinoctiall*-ward towards
either Pole : Or else to be subducted out of the latitude
of that place, if you have sayled towards the *Æquinoctiall*.

Againe if the Ship saile under the *Æquinoctiall* upon
the very line it selfe *Eastward* or *Westward* : it varieth not
the *Latitude* at all : but only changeth the *Longitude* :
and that just so much as the number of degrees it hath
runne in that whole time amounteth unto. Which num-
ber is to be added to, or subducted from the longitude
of

of the place wherein you beganne your account, according as you have sayled *East* or *West*.

And thirdly if the Ship sayle directly *East* or *West* under any parallel circle, that is upon the *East* or *West* Rumbe, be it in the Northerne or Southern Hemisphere, it there also changeth not the *Latitude* at all, but only the *Longitude*: yet not according to the number of *Iust Degrees* it hath gone, as under the *Æquinoctiall*: but more then so many, according as the proportion is betweene that parallel and the *Æquinoctiall*. For the lesser every parallel is, the greater must needs bee the difference of the *Longitude* in sayling so many *Iust Degrees* under it.

Quest: I. By the way of a Ship upon a parallel being given in *Iust Degrees*, to finde how many degrees the *Longitude* is varied.

This is done at one operation by *Theor*: I.

As the sine of the complement of the parallel, is
to the *Radius*:

So is the way of the ship upon that parallel in *Iust Degrees*,
to the degrees of the difference of *longitude*.

An Example. A ship making her course upon the parallel distant from the *Æquinoctiall* degr: 51, min: 32, by the estimation of the way hath sayled 94 in *Iust degrees*: how many proper degrees of that parallel hath shee gone?

The complement of 51°, 32' is 38°, 28', the sine whereof is 62206. Say therefore.

$$\begin{array}{rclclcl} s\ 38^{\circ}, 28' & . & \text{Rad} & :: & 94 & . & 15114 \\ 62206 & & 100000 & & & & \end{array}$$

E 2

The

The difference of longitude sought is degr: $151^{\circ}11'$ + :
Which arch so found is to bee added to, or subducted
from the longitude of the place where you beganne your
account, according as you have sayled either East or
West.

Quest: II. How many English miles change one
degree of longitude in going Eastward or Westward at
the elevation of the Pole degr: 51 , min: 32 .

It was supposed in the beginning of Chapt: III,
that miles $66\frac{1}{4}$ doe answer to one degree of a great cir-
cle upon the earth.

The complement of $51^{\circ}, 32'$ is $38^{\circ}, 28'$.

Say therefore by Theor: I.

$$\begin{array}{rcl} \text{Rad.} & . & 38^{\circ}, 28' :: 66\frac{1}{4} . 41^{\circ}11' \\ 100000 & & 62206 \end{array}$$

Wherefore miles $41^{\circ}11'$ make a degree on the pa-
rallel $51^{\circ}, 32'$.

Keepe this number $41^{\circ}11'$ in mind for the resolving
of the two questions following.

Quest: III. There are two places having the same
latitude of degr: 51 , min: 32 : and the difference of
their longitudes is degr: $151^{\circ}11'$ + : How many miles are
they distant by the parallel?

First find out the number of miles answering to one
degree in the parallel $51^{\circ}, 32'$, by Quest: II. which you
shall find $41^{\circ}11'$. Then multiply the same by the de-
grees of the difference of longitude $151^{\circ}11'$ + : thus,

$$1 . 41^{\circ}11' :: 151^{\circ}11' + . 62274 .$$

Their distance is miles 62274 .

Quest.

Quest: IIII. There are two places having the same latitude of degr: 51, min: 32: and they are distant by the parallel miles 622,740: how many degrees are they distant in longitude?

First find our the number of miles answering to one degree in the parallel 51°, 32', by *Quest: II.* Which you shall finde 41,211. Then by the same number found divide the sum of the miles given, that is 622,740: thus,

$$41,211 \cdot 1 :: 622,740 \cdot 15,1114 \cdot$$

The distance of longitude is degrees 15,1114.

CHAP. VI.

Of the oblique Rumbes betweene the Meridian, and that of East and West; what they are, and how composed: of finding out certaine fundamentall Theoremes for oblique sayling.

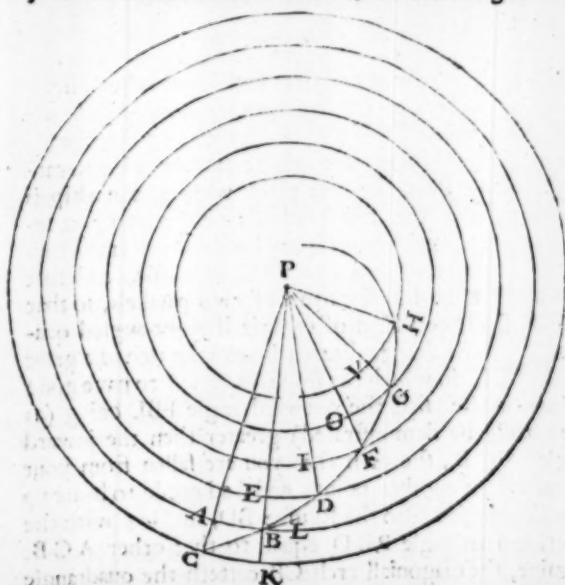


Hat circular sayling upon any one of those foure cardinall points, whether it bee a great circle, or a parallel, hath (as wee have seene) no great difficulty in understanding or computing: so that you bee sure of the true measure of the ships way: because that therein either only the latitude, or only the longitude is altered.

But there is greater difficultie in *oblique sayling* when the Ship runneth upon some Rumb between any of the foure cardinall points, making an oblique angle with the Meridian: because therein the ship continually changeth both latitude and longitude, And the difficulty is so much the greater by how much the voyage is more distant from the Æquinoctial towards either Pole: and upon a Rumb more remote from the Meridian. For neere the Æquinoctiall, where the Meridians are almost parallel; and in those Rumbes which are neere the Meridian, where the longitude is but little altered; there is no such lubricity and propensenesse to erre.

In this kind of *oblique sayling*, the ship is so directed by the Compass, and guided by the helme, that the line of the ships length is every where kept firmly in one and the same angle with the Meridian, according to the distance of that Rumb from the North and South line. And because the Compass is as it were a moveable Horizon: and the lines of direction thereupon are the *intersections*

sections of Azimuths or verticle circles with the same Horizontall plaine, dividing it into so many parts, which are called *Rumbes*: it commeth to passe that in such oblique sayling towards the apparent pole, the place whereunto the Compasse leadeth is evermore betweene the parallel through the place wherein you are, and the Pole. Wherefore the *line of the Ships oblique course* is a *helix* or *spirall* line, approaching neerer and neerer to the Pole, but never falling into it. As in the Scheme, suppose the center of the circle P to be the Pole of the world; and all the concentric circles to be parallels described at equal distance one from the other; and the streight lines



out of the Pole, PAC, PEB, PiD, POF, &c. intersecting those parallels in the points C, B, D, F, &c. to be Meridians

ans : so that all the segments of the Meridians CA, BE, DI, &c. be equall : and all the segments of the parallels KC, BA, DE, &c. be of equall length, though not of equall degrees; every one of those arches containing foure or more degrees, according as every circle is greater or lesse then another. Suppose also that the ship keeping a just North-East course describeth the crooked line CBDF, which therefore must needs be the North-East Rumbe : and in the continuation of it doth approach unto the Pole neerer and neerer : but can never fall into the Pole : because it still keepeth the same distance upon the Compass betweene the Meridian, and the parallel in which it is, and maketh with the Meridian an angle of 45 degrees.

These Helices or spirall lines (which are the oblique Rumbes) ought to consist of most minute and insensible, yea indivisible parts : for if they be any whir great, the account of the Ships motion will be confounded, and carryed downe from the true place whither the ship is gone, towards the Æquinoctiall : neither can you returne by the Rumbe you came. For imagine in the former Scheme two Meridians PAC, and PBK, and that AB and CK be like segments of two parallels, so that ABCK shall be a kind of sphericall right-angled quadrangle : draw therein diagonall-wise the arch of a great circle CBL, in which the ship is supposed to have gone from C to B : first the outward angle PBL being (as may easily be demonstrated) greater then the inward angle ACB, sheweth that you are fallen from your Rumbe into another point ; and had neede to beare up the Ship againe into the Rumbe BD, making with the Meridian an angle PBD equall to that other ACB. Again, the diagonall arch CB cutteth the quadrangle into two triangles unequall one to the other : for though in both the sides AC and BK (which we will call the

eastheis)

catheti) be equall, and the hypotenusa CB be the same : yet the bases AB & CK, and likewise their angles, are unequall : yea though the distance of the parallels AC and BK be but one scruple of a degree. But yet the lesse you take the distance of the parallels, that inequality will also bee the lesse. So that if by any artifice it may bee brought about that the arch AC be not one minute of a degree, which on the face of the earth answereth to above an English mile, but the hundred-thousandth, or if need bee the millioneth part of a minute, scarce exceeding one fifteenth part of an inch (which thing by the helpe of God the giver of all light I have discovered, and am able to performe in tables unto the Radius 10000000, yet nothing at all differing either in their forme or manner of working from those that are now commonly in use) all that inequality will be taken away, and those most small triangles will indeed, and unto all use, become plaine rectangled triangles : and the *spirall line of the ships course* be recalled to a precise exactnesse. By what artifice this is done, together with other secrets of that nature, I may peradventure hereafter be induced to declare ; if so be I shall first see the practisers of this most noble and usefull science (which is as it were the band and tye of most disjunct countries, and the consociation of nations farthest remote) willingly to relinquish their inveterate errors, and to use thankfully and conscionably, without envy and selfe-conceited stubbornnesse, such light and helpes as the due and mature studie of true art shall afford.

In the meane time we will here make use of the ordinary canon of the Meridian divided according to Mercator : which I have therefore set upon the sixth and seventh Circles of this Instrument, unto 70 degrees : as hath bene before shewed in the second part of the first Chapter.

And first out of the inspection of the Rumb in the last diagram compacted of the *hypotenuse* of an infinite number of those minute rightangled triangles, I wil in certain Theoremes demonstrate the *ground of oblique sayling*: And then in the next Chapter apply the same foundations to the answering of the *severall questions in Navigation*.

And because those triangles are all supposed to bee equall (or rather the same triangle so often multiplied) let them be also noted with the same letters A B C, as the lowest of them is: the *catheti* C A being all on the *Meridians*: and the *bases* B A being all on the severall parallels: and the *hypotenuse* C B are the motion of the ship upon the Rumb.

The *Theoremes* are set downe in these proportions.

Theor: I. As the Radius, is
to the sine of the complement of the *Rumb*:
So is the *way of the Ship in degrees* upon that Rumb,
betweene any two places on the earth,
to the *difference of latitude* betweene those two
places.

For R . s.co C :: BC . CA :: many BC . so many CA.

And so conversely.

Theor: II. As the Radius, is
to the sine of the *Rumb* from the Meridian:
So is the *way of the ship in degrees* upon that rumb, &c.
to the *summe of the bases of all the triangles inter-*
cepted betweene the parallels of those two places.

For R . s C :: BC . BA :: many BC . so many BA.

Theor.

Theor: III. As the Radius, is
to the tangent of the *Rumbe* from the Meridian:
So is the difference of latitude between any two places,
to the summe of the bases of all the triangles intercepted, &c.

For $R . \pm C :: CA . BA :: \text{many } CA . \text{ so many } BA .$

Theor: IIII As the Radius, is
to the summe of the secants of all the parallels between
any two places upon the earth:
So is the base of one of those triangles,
to the difference of longitude between those two places.

For by *Theoreme II*, Chap: 5.

$R . \sec : \text{parall} :: \text{base } AB . \text{ diff: of long} : \text{in}$
 $\text{base } BA :: \text{many } \sec : \text{parall} . \text{ diff: of long} : \text{in so}$
 $\text{many bases } BA .$

Again because by the last *Theoreme*

$R . \text{sum} : \sec . \text{parall} :: BA . \text{diff: long} : \text{in } BA .$

and by *Theor: III*. $R . \pm C :: CA . BA .$

and because that CA is but 1, be it *sexagesime* or *centesimal*, &c. therefore by composition of those two proportions aritheth,

Theor: V. As the quadrat of the Radius, is
to the summe of the secants of all the parallels
between any two places upon the earth:

Or, As the Radius, is
to the summe of the secants of all the parallels between
any two places, divided by the Radius:
So is the tangent of the *Rumb* from the Meridian,
to the difference of longitude between those two places.

CHAP. VII.

*Of the severall questions which are incident
unto oblique sayling.*

IT is needfull to bee advertised : First, that in working the questions following upon the Instrument, the *degrees of the ships way* (found out by Chapt : IIII.) and of the *differences both of latitude and longitude*, and also the *summe of the secants of parallels*, are all to be taken on the *fourth circle*, after the manner of absolute numbers : for which cause they are still to be set downe in *degrees and Decimall parts of degrees*. But the *Sines and Tangents* are to be accounted in *their owne circles*. That heereafter wee may not neede evermore to bee telling unto what circle every number or terme doeth belong,

And secondly, that if you please to worke these questions with your pen : you may doe it by the tables for the division of the *Meridian line according to Mercator* : Which tables are nothing else but a perpetuall addition of secants. And are to be found both in *Master Wrights Errors of Navigation*, and in *Willibrordus Snellius his Tiphys Batavus*, for every minute : and in *Master Gunters Booke* for every tenth part of a degree. Which last for more readinesse sake I doe herein make use of.

But in using the tables of *Master Wright* or *Snellius*, you must reckon the *latitudes in degrees and minutes* ; with *Decimalls of Minutes*, and not in *Decimalls of Degrees*.

In

In the examples I have set downe the numbers so, that you may worke them either by the Instrument, or with the pen. The manner of working the Decimall parts with the penne you shall find in my *Clavis Mathematica*, Chapt. 1, 2, 3, 4, 6. But by the Instrument, in the first Chapter of this present tractate at large : which I could wish were dilligently studied and practised. •

And now I come to the Questions.

QUEST. I. By the Rumbe and way of the Ship given, to find the difference of latitude betweene two places.

This is done at one operation by *Theor*: I. in the former Chapter.

As the Radius, is
to the sine of the complement of the Rumbe :
So is the way of the ship in degrees upon that rumbe,
betweene any two places on the earth,
to the difference of latitude betweene those two places.

An Example. A Ship beginning her course in the latitude of degr: $50^{\circ} 17'$, that is $50^{\circ} 42'$, hath sayled on the *NWbN* Rumbe degr: $9^{\circ} 36'$ into what latitude is she come?

Here the angle of inclination which the *NWbN* Rumbe maketh with the Meridian is (by Chap: III.) $33^{\circ} 45'$: the complement of which is $56^{\circ} 15'$: and the sine thereof $83^{\circ} 147'$. Say therefore,

Rad : $56^{\circ} 15'$:: $9^{\circ} 36'$: $7^{\circ} 78'$; the
100000 83147. (difference of latitude

F 3

which

which being added to the Latitude $50^{\circ} 17'$ given (because the greater latitude is sought) giveth degrees $58^{\circ} 42'$. that is, $58^{\circ}, 29'$.

But if the lesser latitude had bene sought: the said difference should have bene subducted out of the latitude given. And if the difference of latitude found (the Ship sayling toward the *Æquinoctiall*) chance to exceed the latitude given, subduct the latitude given out of the said difference found: and the remaines shall bee the second latitude, but in the contrary Hemisphere. For if the two latitudes be in the contrary hemispheres, the summe of both is the difference betweene them.

QUEST. II. By the way of the Ship and the difference of latitude betweene two places given, to finde the Rumb leading from one place to the other.

This is done also at one operation by the said *Theoreme I.*

As the way of the Ship in degrees upon the Rumb sought betweene any two places, is
to the difference of latitude between those two places:
So is the Radius,
to the sine of the complement of the Rumb sought.

An Example. A Ship beginning her course at the latitude of degrees $50^{\circ} 17'$, that is $50^{\circ}, 42'$, hath sayled up to the latitude of degrees $58^{\circ} 42'$, that is $58^{\circ}, 29'$: in which space it hath gone degrees $91^{\circ} 36'$ upon one Rumb. What Rumb was it that she followed?

Here the difference of latitude is degrees $77^{\circ} 82'$. say,

$$91^{\circ} 36' \cdot 77^{\circ} 82' :: \text{Rad} \cdot 56^{\circ}, 15' : 83^{\circ} 147'$$

the

the complement of which arch found is $33^{\circ}, 45'$: which is the angle of inclination of the Ships course to the Meridian: and is (by Chapt: III.) the *NW b N* Rumbe.

QUEST. III. *By the Rumbe, and difference of latitude between two places, to find the quantity of the Ships way in degrees.*

This is done at one operation by the converse of the said Theor: I,

As the sine of the complement of the Rumbe, is
to the Radius :

So is the difference of latitude between any two places
to the measure of the Ships way in degrees.

An Example. A Ship beginning her course at the latitude of $\text{degr} : 58^{\circ} 14' 2''$, hath sailed upon the *SE b S* Rumbe unto the height of $\text{degr} : 50^{\circ} 7'$: how many degrees hath shee gone upon the Rumbe?

Here the difference betweene the two latitudes given is $\text{degr} : 7^{\circ} 7' 2''$. And the angle of inclination of the *SE b S* Rumbe is $33^{\circ}, 45'$, by Chapt: III: the complement of which is $56^{\circ}, 15'$: and the sine thereof 83147 . Say therefore.

$56^{\circ}, 15'$. Rad :: $7^{\circ} 7' 2''$. 9136 :

which is the measure of the Ships way in degrees.

QUEST. IIII. *By the Rumbe, and difference of latitude, to find the difference of longitude.*

This is done at one operation by Theor: V, in the former Chapter.

As

As the Radius, is

to the tangent of the Rumb :

So is the summe of the secants of the parallels between any two places, divided by the Radius : as they are set downe in the tables,

to the difference of longitude between the Meridians of those two places.

An Example. A Ship beginning her course at the latitude of degr : $38^{\circ}12'$, sayleth upon the *WbN* Rumb, unto the latitude of degr : $50^{\circ}15'$: how many degrees of longitude hath it varied in that course ?

Here the angle of inclination of the *WbN* Rumb with the Meridian is $78^{\circ}, 45'$: the tangent whereof is 502734 . And the summe of the secants for $50^{\circ}15'$ is $58,691$: and the summe of the secants for $38^{\circ}12'$ is 411392 : the difference of which is 171299 , the summe of the secants of the parallels between those two latitudes : which else by the Instrument is found out by the second part of the first Chapter. Say therefore,

$$\begin{array}{rcl} \text{Rad} & . & 100000 \\ & : & 502734 \\ & : & 78^{\circ}, 45' \\ & :: & 171299 . 871227 : \end{array}$$

Which is the difference of longitude between the Meridians of the two places.

But because this question is of excellent and very frequent use, it will not be amiss to set downe at large the manner of working this Example upon the Instrument. Thus,

Set one of the armes of the Index upon $38^{\circ}12'$ in the sixth circle, and open the other arme unto $50^{\circ}15'$ in the seventh circle, according as hath beene taught in the second part of the first Chapter. Then move the arme of the

the Index, which stood on 38° to the line of the $\mathbf{I}$: and the other arme at the same opening shall in the *fifth circle* cut $171^{\circ}29'$, the summe of the secants.

Again set one of the armes of the Index upon the line of the Radius, and open the other arme unto the tangent of $78^{\circ}, 45'$. Then move the antecedent arme of the Index, which stood at the line of the Radius, unto $171^{\circ}29'$ in the fourth circle: and the consequent arme shall in the same fourth circle cut $87^{\circ}27'$, which are the degrees of the difference of longitude sought for.

QUEST V. By the latitude and longitude of any two places given, to find what Rumbeth leadeth from the one place to the other.

This is done at one operation by the same Theor: V.

As the summe of the secants of the parallels betweene those two places, is

to the difference of longitude betweene them :

So is the Radius,

to the tangent of the Rumbeth sought.

An Example. There are two places, the one having the latitude of $\text{degr} : 50^{\circ}15'$: and the other the latitude of 38° . And the difference of longitude betweene their Meridians is $\text{degr} : 87^{\circ}27'$. By what Rumbeth shall a Ship sayle from one place to the other ?

Here the summe of the secants of the parallels betweene the two latitudes given is $171^{\circ}29'$, as was found out in the example of Quest. IIII. Say therefore,

$$171^{\circ}29' \cdot 87^{\circ}27' :: \text{Rad} \cdot 78^{\circ}, 45' :$$

$$100000 \quad 205734$$

G

Which

Which is the *angle of the inclination of the Rumb leading between those two places, with the meridian*: and is therefore (by the third Chapter) the *WbN* or *EbSRumb*: if the latitudes be on the North side of the *Æquinoctiall*.

QUEST. VI. *By the Rumb, and difference of longitude between two places, whereof one is given, to find the difference of their latitudes.*

This is done at one operation by the converse of *Th. V.*

As the tangent of the Rumb, is
to the Radius :

So is the difference of longitude between the Meridians of those two places,
to the summe of the secants of the parallels between those two places.

An Example. A Ship beginning her course at the latitude of $\text{degr: } 38^{\circ}$, sayleth upon the *WbN* Rumb untill it hath changed the longitude $\text{degr: } 87^{\circ}27'$: Into what latitude shall she then be come?

Here the angle of inclination of the *WbN* Rumb with the Meridian is $78^{\circ}, 45'$. Say therefore,

$$78^{\circ}, 45' \cdot \text{Rad} :: 87^{\circ}27' \cdot 17^{\circ}29' :$$

Which is the *summe of the secants of the parallels between the latitude $\text{degr: } 38^{\circ}$ given, and the latitude of the place wherein the Ship is.* Wherefore if unto the summe of the parallels for $\text{degr: } 38^{\circ}$ found out by the second part of Chap: I. namely $41^{\circ}39'$, you adde the fourth terme found $17^{\circ}29'$: the summe $58^{\circ}9'$ shall bee the *summe of the parallels for the latitude sought* : which by the said second part of Chap: I. you shall finde to bee degrees 50° .

QUEST.

QUEST. VII. By the Rumb, and measure of the way of the Ship in degrees, to find the difference of longitude between two places, whereof one is given.

— This is done by two operations.

The first is, By the Rumb, and way of the Ship given, to finde the difference of latitude: which is *Quest. I.*

The second is, By the Rumb, and difference of latitude given, to finde the difference of longitude, which is *Quest. III.*

An Example. A Ship beginning her course in the latitude of degr: $50^{\circ}4'$ hath sayled upon the *WNW* rumb deg: 137° : how much hath she changed the longitude?

Here the angle of inclination of the *WNW* Rumb with the Meridian is $67^{\circ}, 30'$: the compl: of which is $22^{\circ}, 30'$ the sine whereof is 38268. Say first by *Quest. I.*

$$\begin{array}{rcl} \text{Rad} & . & s\ 22^{\circ}, 30' :: 137^{\circ} \quad . \quad 51^{\circ}4' \\ 100000 & & 38268 \end{array}$$

Which is the difference of latitude between the beginning and the place where the Ship is. Now because the Ship sayling toward the Pole increaseth the latitude: Adde degr: $51^{\circ}4'$ to degr: $50^{\circ}4'$ the latitude given: and the sum deg: $55^{\circ}8'$ shall be the latitude of the place whither he Ship is come.

Seeke the summe of the secants of the parallels for both those places, by the second part of Chap: I, which will be found to be 58134, and 67250: the difference of which two numbers is 8725, the summe of
 C 3 the

Of Navigation.

the secants betweene those parallels. Also the tangent of the Rumb, (*viz*) of $67^{\circ}, 30'$ is 241421.

Say therefore againe by *Quest.* IIII.

$$\begin{array}{rcl} \text{Rad} : 167^{\circ}, 30' :: 8125 & . & 211064 \\ 100000 & & 241421 \end{array}$$

Which arch of degr: 211064 is the difference of longitude sought for.

QUEST. VIII. By the difference of latitude, and measure of the way of the Ship in degrees: to finde the difference of longitude betweene two places, whereof one is given.

This also done by two operations.

The first is, By the difference of latitude, and the way, to finde the Rumb: which is *Quest.* II.

The second is, By the Rumb, and difference of latitude, to finde the difference of longitude: which is *Quest.* IIII.

An Example. A Ship beginning her course in the latitude of degr: $55^{\circ}, 64'$, hath sayled degr: $13^{\circ}, 7'$ upon one and the same Rumb; even unto the latitude of degr: $50^{\circ}, 4'$: how many degrees of longitude hath she changed?

Here the difference betweene the two latitudes given degr: $51^{\circ}, 24'$

Say first by *Quest.* II,

$$\begin{array}{rcl} 13^{\circ}, 7' & . & 51^{\circ}, 24' :: \text{Rad} & . & 22^{\circ}, 30' \\ 100000 & & 38168 \end{array}$$

the

the complement of which arch (*viz*) $67^{\circ}, 30'$, is the angle of the Rumb: And the tangent thereof is 241431 . Seeke also the summe of the secants of the parallels for both those places, by the second part of Chap. I: which will be found to bee 581534 , and by 67152 : the difference of which two numbers is 8715 , the summe of the secants betweene the parallels.

Say therefore againe by *Quest. III*,

$$\begin{array}{rcll} \text{Rad.} & : & 67^{\circ}, 30' & :: 81725 & . & 211064 \\ 100000 & & 241431 & & & \end{array}$$

Which arch of degr: 211064 is the difference of longitude sought for.

QUEST. IX. By the differences of latitude and longitude betweene two places, given, to finde the measure of the way of the Ship in degrees.

This is also done by two operations.

The first is, By the difference of latitude and longitude to finde the Rumb leading betweene those two places: which is *Quest. V*.

The second is, By the Rumb, and difference of latitude, to find the measure of the Ships way in degrees: which is *Quest: III*.

An Example. A Ship beginning her course in the latitude of degrees 5014 , sayleth still following one and the same Rumb untill shee commeth to the latitude of degr: 55164 : in which time she hath changed the longitude degr: 211064 : How many degrees hath the Ship gone upon that Rumb?

Here, the summe of the secants of the parallels for both the places proposed, by the second part of Chap. I, will

will be found to be $58^{\circ}34'$, and $67^{\circ}59'$: the difference of which two numbers is $8^{\circ}25'$, the summe of the secants of the parallels betweene those two latitudes.

Say first by *Quest. V.*

$$\begin{array}{rcll} 8^{\circ}25' & . & 211^{\circ}64' & :: \text{Rad} . : 67^{\circ}30' : \\ & & & 100000 \quad 241431 \end{array}$$

Which is the angle of inclination of the *Rumbe*, with the *meridian*: the complement of which is *degr*: 22, *min*: 30: the sine whereof is 38268. And the difference between the two latitudes *degr*: $55^{\circ}64'$, and *degr*: $50^{\circ}14'$, is *degr*: $5^{\circ}14'$.

Say therefore againe by *Quest. III.*

$$\begin{array}{rcll} 52^{\circ}30' & . & \text{Rad} & :: 5^{\circ}14' . 1317 : \\ 38268 & & 100000 & \end{array}$$

Which is the measure of the *Ships way in degrees*.

QUEST. X. By the *Rumbe*, and difference of longitude betweene two places, whereof one is given, to finde the quantity of the way in degrees betweene those places.

This is also done by two operations :

* The first is, By the *Rumbe*, and difference of longitude, to finde out the difference of latitude: which is *Quest. VI.*

The second is, By the *Rumbe*, and difference of latitude, to finde out the measure of the way of the Ship in degrees: which is *Quest. III.*

An Example. A Ship beginning her course in the latitude of *degr*: $55^{\circ}64'$, sayleth upon the *ESE Rumbe* so long

long till it hath changed the longirude degr: $21^{\circ} 64'$.
How many degrees hath the Ship-gone upon that
Rumbe?

Here the angle of the *ESE* Rumbe with the Meridi-
an is degr: 67 , min: 30 ; the tangent whereof
is 241421 .

Say first by *Quest. VI.*

$$167^{\circ}, 30' \text{ . Rad} :: 211064 \text{ . } 81725 :$$

Which is the summe of the secants of the parallels betweene
the latitude of degr: $55^{\circ} 64'$, and the other latitude sought.

Now the summe of the secants of the parallels for the
latitude of degr: $55^{\circ} 64'$ is 671259 , by the second part of
Chap. I. Out of which number if you subduct 81725 last
found (because the course is towards the *Aequinoctiall*)
the remaines shall bee 589534 , the summe of the secants
of the parallels for the other latitude of degr: $50^{\circ} 14'$, by
the same second part of Chapt. I. So that the difference
of the latitudes is degr: $51^{\circ} 24'$. And the sine of $22^{\circ} 30'$,
the complement of the *ESE* Rumbe is 38268 .

Say therefore againe by *Quest. II.*

$$122^{\circ}, 30' \text{ . Rad} :: 5124 \text{ . } 1317 \\ 38268 \text{ } 10000$$

Which is the quantity of the Ships way in degrees.

QUEST. XI. By the way of the Ship and the difference of
longitude betweene the Meridians of any two places, where-
of one is given, to find out the Rumbe leading from one place
to the other.

QUEST.

QUEST. XII. By the way of the Ship, and the difference of longitude betwene the Meridians of any two places, whereof one is given, to finde out the difference of their latitudes: by which the other place may be had.

These two *Questions*, as they are of little or no use in Navigation; so also they have no direct and immediate solution. But are performed after the manner of the rule of false position, by supposing reasonably either a Rumb, or another latitude: and then according to *Quest. VII*, and *Quest. V II*, to find the difference of longitudes: which if it chance to fall out to be the same that is given in the *Question*; you have your desire. If not: suppose the second time. And lastly by comparing of both errors argue the truth.

These two *Questions* are not so materiall, that I should spend more time in setting downe Examples thereof. I will leave that worke to the studious practitioner.

QUEST. XIII. If it be required to know the distance upon the Rumb between any two places, the measure of the way being knowne in degrees. You may multiply that measure of the way in degrees by miles 66 $\frac{1}{2}$, which is the number of miles contained in one last degree upon the earth, as was before assumed in Chapr. III.

And thus have I shewed the use of the Instrument in the solution of all nautical *Questions*: which thing I specially in this small tractate aymed at. Which if it shall give any light and satisfaction to such as are studious in that most noble and usefull art, I have my desire: which indeed onely is, that the society of mankind may be benefited, and God glorified, by every poore ability hee hath beene pleased to bestow upon me. I was also in part minded to have annexed herunto certain problemes,
how

how by reasonable conjecture the course of the Ship may be most probably rectified, when the reckoning thereof by the Compasse and way estimated, shall be found to disagree from the celestiaall observations: Wherein I should have occasion to speake of the currents or hidden motions of the Seas, how they are to be observed, and how to be considered of in computing the motion of the Ship: And also of the deflexion (or as I may call it, the *bias*) of the Ship bending and wheeling it selfe about continually to the one side; how, and what allowance may most reasonably be made for it. But because these doe not properly belong to the Instrument, and are to me onely in speculation (which by reason of my want of experience in Nauticall affaires, I cannot so well direct and ordaine for practice at sea) I will for this present prætenuit, contenting my selfe with what hath beene already delivered.

And if the *Masters of Ships* and *Pilots* will take the paines in the journaalls of their voyages dilligently and faithfully to set downe in severall columnes, not only the Rumbes they goe on, and the measure of the Ships way in degrees, and the observations of latitude, and variation of their compasse; but also their conjectures and reasons of the correction they make of the aberrations they shall find, and the quality or condition of their Ship, and the diversities and seasons of the windes, and the secret motions or agitations of the Seas, when they beginne, and how long they continue, how farre they extend, and with what inequallity; and what else they shall observe at Sea worthy consideration, and will be pleased freely to communicate the same with Artists, such as are indeed skilfull in the Mathematicks, and lovers and inquirers of the truth: I doubt not but that there shall in convenient time be brought to light many necessary præcepts, which may tend to the perfecting of navigation, and the help and satisfie of such, whose vocations doe en-

force them to commit their lives and estates in the vast
and wide Ocean to the providence of God :
to whom be all prayse, honour, and
glory : And this is

The End.

*I have at the request of Master Elias Allen, given way
that Master Gunters Table of the division of the Me-
ridian line after Mercator, should be here inserted, for
the use of such as will take the paines to enter into a nu-
merary calculation of the former Problemes. The o-
ther Tables of naturall Sines and Tangents are every
where to be had.*

A Table

A Table for the division

57

M Gr	Par	M Gr	Par	M G	Par	M Gr	Part	M Gr	Part
00	0	3	3 001	6	6 011	9	9 037	12	12 088
	100	3	3 101		6 111		9 138	12	12 190
	200	3	3 201		6 211		9 239	12	12 293
	300	3	3 301		6 311		9 341	12	12 395
	400	3	3 401		6 413		9 443	12	12 497
	500	3	3 501		6 514		9 543	12	12 600
	600	3	3 601		6 614		9 645	12	12 702
	700	3	3 701		6 715		9 746	12	12 805
	800	3	3 801		6 816		9 848	12	12 907
	900	3	3 901		6 916		9 949	13	13 010
1	1 000	4	4 003	7	7 017	10	10 051	13	13 112
	1 100	4	4 103		7 118	10	10 152	13	13 215
	1 200	4	4 204		7 219	10	10 254	13	13 318
	1 300	4	4 304		7 319	10	10 355	13	13 421
	1 400	4	4 404		7 420	10	10 457	13	13 523
	1 500	4	4 504		7 521	10	10 559	13	13 626
	1 600	4	4 605		7 622	10	10 661	13	13 729
	1 700	4	4 705		7 723	10	10 762	13	13 832
	1 800	4	4 805		7 824	10	10 864	13	13 935
	1 900	4	4 905		7 925	10	10 966	14	14 038
2	2 000	5	5 006	8	8 026	11	11 068	14	14 141
	2 100	5	5 106		8 127	11	11 170	14	14 244
	2 200	5	5 207		8 228	11	11 272	14	14 347
	2 300	5	5 307		8 329	11	11 374	14	14 450
	2 400	5	5 408		8 430	11	11 475	14	14 553
	2 500	5	5 508		8 531	11	11 578	14	14 656
	2 600	5	5 609		8 632	11	11 680	14	14 760
	2 700	5	5 709		8 733	11	11 782	14	14 863
	2 800	5	5 810		8 834	11	11 884	14	14 967
	2 900	5	5 910		8 936	11	11 986	15	15 070
3	3 000	6	6 011	9	9 037	12	12 083	15	15 174

M	Gr	Par	M	Gr	Par	M	Gr	Par	M	Gr	Par	M	Gr	Par
15	15	174	18	18	303	21	21	486	24	24	734	27	28	050
	15	277		18	408		21	593		24	844		28	171
	15	381		18	513		21	701		24	953		28	283
	15	485		18	619		21	808		25	063		28	396
	15	588		18	724		21	915		25	173		28	508
	15	692		18	830		21	023		25	282		28	621
	15	796		18	939		22	130		25	392		28	734
	15	900		19	041		22	238		25	502		28	847
	16	004		19	146		23	345		25	613		28	959
	16	107		19	251		23	453		25	723		29	072
16	16	211	19	19	356	22	22	561	25	25	833	28	29	186
	16	316		19	463		22	669		25	943		29	299
	16	420		19	569		22	777		26	054		29	413
	16	524		19	675		22	885		26	164		29	526
	16	628		19	781		22	993		26	275		29	640
	16	732		19	887		23	101		26	386		29	753
	16	836		19	993		23	210		26	497		29	867
	16	941		20	100		23	318		26	608		29	981
	17	045		20	206		23	427		26	719		30	095
	17	150		20	312		23	535		26	830		30	300
17	17	255	20	20	419	23	23	643	26	26	941	29	30	324
	17	359		20	525		23	752		27	052		30	438
	17	464		20	632		23	861		27	164		30	553
	17	568		20	738		23	970		27	275		30	667
	17	673		20	845		24	079		27	387		30	782
	17	778		20	952		24	188		27	499		30	897
	17	883		21	059		24	297		27	610		31	013
	17	988		21	165		24	406		27	722		31	127
	18	093		21	272		24	515		27	834		31	242
	18	198		21	379		24	624		27	946		31	357
18	18	303	21	21	486	24	24	734	27	28	058	30	31	473

of the Meridian line.

59

M	Gr	Part	M	Gr	Part	M	Gr	Part	M	Gr	Part	M	Gr	Part
30	31	473	33	34	992	36	38	633	39	42	415	42	46	362
	31	588		35	111		38	757		42	544		46	496
	31	704		35	231		38	880		42	673		46	631
	31	820		35	350		39	004		42	802		46	766
	31	936		35	470		39	129		42	931		46	902
	32	052		35	590		39	253		43	061		47	087
	32	168		35	710		39	377		43	191		47	173
	32	284		35	830		39	502		43	320		47	309
	32	400		35	950		39	627		43	451		47	445
	32	517		36	071		39	752		43	581		47	581
31	32	633	34	36	191	37	39	877	40	43	711	43	47	718
	32	750		36	312		40	002		43	842		47	855
	32	867		36	433		40	128		43	973		47	992
	32	984		36	554		40	253		44	104		48	129
	33	101		36	675		40	379		44	235		48	267
	33	218		36	796		40	505		44	366		48	404
	33	336		36	917		40	631		44	498		48	542
	33	453		37	039		40	757		44	630		48	681
	33	571		37	161		40	884		44	762		48	819
	33	688		37	283		41	011		44	894		48	958
32	33	806	35	37	405	38	41	137	41	45	026	44	49	097
	33	924		37	527		41	264		45	159		49	236
	34	042		37	649		41	392		45	292		49	375
	34	161		37	771		41	519		45	425		49	515
	34	279		37	894		41	646		45	558		49	655
	34	397		38	017		41	774		45	691		49	795
	34	516		38	140		41	902		45	825		49	935
	34	635		38	263		42	030		45	959		50	076
	34	754		38	386		42	158		46	093		50	217
	34	873		38	509		42	287		46	227		50	358
33	34	992	36	38	633	39	42	415	42	46	362	45	50	499

M	Gr	Part	M	Gr	Part	M	Gr	Part	M	Gr	Part	M	Gr	Part
15	50	499	48	54	860	51	59	441	54	64	412	57	69	711
	50	641		55	010		59	640		64	582		69	895
	50	783		55	150		59	800		64	753		70	080
	50	925		55	310		59	950		64	924		70	263
	51	058		55	460		60	120		65	025		70	449
	51	210		55	611		60	280		65	253		71	635
	51	353		55	752		60	441		65	440		70	811
	51	495		55	913		60	602		65	613		71	003
	51	639		56	055		60	753		65	735		71	195
	51	783		56	217		60	925		65	960		71	383
45	51	927	49	55	369	52	51	038	55	65	134	58	71	572
	52	071		56	522		61	200		66	308		71	761
	52	215		56	675		61	413		66	483		71	950
	52	360		56	828		61	577		66	659		72	140
	52	505		56	981		61	740		66	835		72	331
	52	650		57	135		61	904		67	011		72	522
	52	795		57	289		62	059		67	188		72	714
	52	941		57	444		62	234		67	365		72	905
	53	087		57	598		62	399		67	543		73	099
	53	233		57	754		62	564		67	721		73	292
47	53	380	50	57	909	52	61	710	56	67	900	59	73	486
	53	526		58	065		62	877		68	079		73	680
	53	673		58	221		63	053		68	258		73	875
	53	821		58	377		63	231		68	433		74	071
	53	958		58	534		63	398		68	618		74	257
	54	116		58	691		63	566		68	799		74	464
	54	264		58	848		63	734		68	981		74	661
	54	413		59	006		63	903		69	163		74	859
	54	562		59	164		64	072		69	345		75	057
	54	711		59	322		64	242		69	528		75	256
48	54	860	51	59	481	54	64	412	57	69	711	60	75	456

A Table for the division of, &c.

61

M	Gr	Part	M	Gr	Part	M	Gr	Part	M	Gr	Part	M	Gr	Part	M	Gr	Part
60	75	456	63	81	749	66	88	735	69	96	575	72	105	575	75	105	575
	75	656		81	970		88	571		96	854		105	904		105	904
	75	857		82	191		89	219		97	135		106	230		106	230
	76	059		82	413		89	467		97	418		106	558		106	558
	76	261		82	635		89	716		97	701		106	888		106	888
	76	464		82	860		89	967		97	986		107	220		107	220
	76	667		83	084		90	218		98	272		107	553		107	553
	76	871		83	311		90	470		98	560		107	888		107	888
	77	076		83	536		90	723		98	849		108	216		108	216
	77	281		83	763		90	978		99	139		108	565		108	565
61	77	487	64	83	990	67	91	232	70	99	431	73	108	906		108	906
	77	694		84	219		91	489		99	724		109	249		109	249
	77	901		84	448		91	746		100	018		109	594		109	594
	78	109		84	678		92	005		100	314		109	941		109	941
	78	317		84	909		92	264		100	612		110	290		110	290
	78	526		85	141		92	525		100	910		110	641		110	641
	78	736		85	374		92	787		101	211		110	994		110	994
	78	947		85	607		93	050		101	513		111	349		111	349
	79	158		85	842		93	314		101	816		111	707		111	707
	79	370		86	077		93	579		102	121		112	066		112	066
62	79	583	65	86	313	68	93	846	71	102	427	74	112	428		112	428
	79	796		86	550		94	113		102	735		112	792		112	792
	80	010		86	788		94	382		103	044		113	158		113	158
	80	225		87	027		94	652		103	356		113	526		113	526
	80	441		87	267		94	923		103	668		113	897		113	897
	80	657		87	508		95	195		103	983		114	270		114	270
	80	874		87	749		95	468		104	229		114	645		114	645
	81	091		87	992		95	743		104	616		115	023		115	023
	81	310		88	235		96	019		104	936		115	403		115	403
	81	529		88	480		96	296		105	257		115	786		115	786
63	81	749	66	88	725	69	96	575	72	105	579	75	116	171		116	171

M	Gr.	Part	M	Gr.	Part	M	Gr.	Part	M	Gr.	Part	M	Gr.	Part
75	116	171	78	129	075	81	145	650	84	168	947	87	208	705
	116	559		129	558		146	292		169	912		210	649
	116	949		130	045		146	942		170	893		212	668
	117	342		130	536		147	600		171	891		214	745
	117	737		131	031		148	265		172	907		216	909
	118	135		131	530		148	937		173	941		219	158
	118	536		132	034		149	618		174	994		221	498
	118	639		132	542		150	307		176	067		223	938
	119	345		133	055		151	003		177	160		226	486
	119	755		133	572		151	709		178	275		229	153
76	120	166	79	134	094	82	152	423	85	179	411	88	231	950
	120	581		134	620		153	147		180	569		234	891
	121	000		135	151		153	878		181	752		237	991
	121	420		135	687		154	620		182	960		241	268
	121	843		136	228		155	372		184	194		244	744
	122	270		136	775		156	132		185	454		248	445
	122	700		137	326		156	903		186	743		252	402
	123	133		137	883		157	685		188	062		256	652
	123	570		138	445		158	478		189	411		261	243
	124	009		139	012		159	281		190	793		266	235
77	124	452	80	139	585	83	160	096	86	192	210	89	271	705
	124	898		140	164		160	922		193	661		277	753
	125	348		140	748		161	761		195	151		284	517
	125	801		141	339		162	612		196	680		292	191
	126	258		141	936		163	475		198	251		301	058
	126	718		142	538		164	352		199	867		311	163
	127	182		142	147		165	242		201	529		324	455
	127	649		143	763		166	146		203	240		341	166
	128	121		144	385		167	065		205	005		365	039
	128	596		145	014		167	999		206	825		408	011
78	129	075	81	145	650	84	168	947	87	208	705	90	Infinite.	



The Declarat ion of t he two RVLERS for *Calculation.*

THe *Rulers* are so framed and composed, that they may not only be applied to the calculation of *Triangles*, and the resolution of *Arithmetical Questions*: but that they may also very fitly serve for a *Grosse-staffe* to take the height of the *Sunne*, or any *Starre* above the *Horizon*, and also their distances. In which regard I call the longer of the two *Rulers* the *Staffe*, and the *Shorter* the *Transuersarie*. And are in length one to the other almost as 3 to 2.

The *Rulers* are just foure square, with right angles: and equall in bignesse: they are thus divided.

The *Transuersarie* at the upper end noted with the letters *S, T, N, E*, on the severall sides, hath a *pinnicicle* or *sight*: at the lower edge of which sight is the line of the *Radins*, or *Vnise line*, where the divisions beginne.

On the left edge of one of the sides are set the *Degrees* from 0 to 33 degrees. And on the right edge of the same side is set the line of *Sines* from 90 to 1 degree.

In the next side are set two lines of *Tangents*, that on
I the

the right edge goeth upward from 1 to 45 degrees: and that on the left edge goeth downward from 45 to 89 degrees.

In the third side, on the right edge is set the *line of Numbers*, having these figures in descent, 1, 9, 8, 7, 6, 5, 4, 3, 2, 1, 9, 8, 7, &c.

In the fourth side on the right edge is set the *line of Equall parts*: And on the left edge are diverse *chords* for the dividing of Circles..

The *Staffe* at the further end of it hath a *socket* with a *pinnicid* or *sight*: at which beginneth the 30 degree, and so goeth on to 90 degrees at the end of the *Staffe* next your eye: which degrees from 30 to 90 are set on the right edge of one of the sides of the *Staffe*.

Then applying your *Transversarie* to the *Staffe* with the lower end set to 90, marke on the four sides of the *Staffe* the *line of the Radius* or *Vnise*: at which on every left edge must beginne the *single line of Sines, Tangents, and Numbers*, the very same which were in the *Transversarie* (that of the *Sines* being on that side where the degrees are) only the *line of Tangents*, and *numbers* are continued beyond the line of the *Radius*, to the further end of the *Staffe*.

And on the fourth side of the *Staffe* in the middle are *double divisions*: that on the right hand is a *line of Equall parts* to 100, reaching the whole length of the *Staffe*: And on the left hand contiguous to the former, is the *line of Latitudes or Elevations of the Pole* unto 70 degrees marked with the letter *L*.

The degrees both of the *Staffe*, and *Transversarie*, and
also

also of the Sines and Tangents may bee divided into 6 parts which containe 10 minuts apiece: or rather into 10 parts containing 6 minuts apiece: for so they may serve also for Decimals.

Thus have you on the *two Rulers* the very samelines which are in the *Circles of Proportion*: and whatsoever can be done by those *Circles*, may also as well be performed by the two *Rulers*: and the *Rules* which have bin here formerly set downe for that Instrument, may also be practised upon these: so that you bee carefull to observe in both the different propriety in working. It will not therefore be needfull, to make any new and long discourse, concerning these *Rulers*, but onely to shew the manner, how they are to be used, for the calculation of any proportion given.

In working a Proportion by the *Rulers*, hold the *Transversary* in your left hand, with the end at which the line of the *Radius* or *Vnite line* is, from you ward: turning that side of the *Ruler* upward, on which the line of the kind of the first terme is, whether it be *Number*, *Sine*, or *Tangent*: and therein seeke both the first terme, and the other which is homogeneous to it. Then take the *Staffe* in your right hand with that side upward, in which the line of the kind of the fourth terme sought for is: and seeke in it the terme homogeneous to the fourth. Apply this to the first terme in the *Transversarie*: and the other homogeneous terme shall in the *Staffe* shew the fourth terme.

As if you would multiply 355 by 48: Say

$$1 \cdot 355 :: 48 \cdot 17040 \cdot$$

For if in the line of *Numbers* on the *Staffe* you reckon 355, and apply the same to 1 in the line of *Numbers* on the *Transversarie*; then shall 48 on the *Transversarie* shew 17040 on the *Staffe*.

Again if you would divide 17040 by 48 : Say

$$48 \cdot 1 :: 17040 \cdot 355$$

For if in the line of Numbers on the Transversarie you reckon 48, and to the same apply 1 in the line of Numbers on the Staffe : then shall 17040 on the Transversarie shew 355 on the Staffe.

The true value of the fourth terme found, may be had by the 5 & 6 sect : 2 chap : 1 part.

Some Examples of working Proportions wee will borrow out of 3 chap : 1 part

Example I. If 54 elnes of Holland be sold for 96 shillings : for how many shillings shall 9 elnes be sold ? the worke shall be thus

$$54^{\text{el}} \cdot 96^{\text{sh}} :: 9^{\text{el}} \cdot 16^{\text{sh}}$$

for if in the line of Numbers on the transversarie you seeke the first terme 54 elnes, and in that line on the Staffe you seeke 96 shillings : and apply one to the other : then shall 9 elnes fought out on the Transversarie point out 16 shillings on the Staffe.

Example IIII. There is a Tower whose height I would measure.

I take two Stations in the same right line from the Tower : and at either station having observed the height by the sights of the Staffe, I find the neerer station 28 deg : 7 min : almost : and the further station 21 degr : 58 minutes alm ost : and betweene both the Stations the distance was 76 feet.

The

The rule of measuring heights by two stations is contained in these *Theoremes*.

THEOR. *As the difference of the Tangents of the arches cut in either Station, is to the distance betweene the stations: so is the Tangent of the lesser arch, to the neerer distance from the Tower.* Again

THEOR. *As the Radius is to the Tangent of the greater arch; so is the neerer distance found, to the height.*

And therefore because according to 6 sect: I chap: 1 part, by application of the line of Numbers to the line of Tangents (*that is by applying the Vnite line of the Staffe, to the Tangent in the Transversarie, if the arch be lesse then 45 degr: but if the arch exceed 45 degr: by applying the said Vnite line, unto the arch it selfe, or the complement thereof, which in the Transversarie is all one*) the Tangent of $28^{\circ}, 7'$ is 5343, and the tangent of $21^{\circ}, 58'$ is 4033: whose difference is 1310: the Proportions will in the lines of Numbers be thus

First, $1310 \cdot 76 :: 4033 \cdot 234$

wherefore 234 feet is the neereft distance

Second. Radius . tang: $28^{\circ}, 7'$:: 234 . 125

wherefore 125 feet is the height sought for.

Or else you may resolve it at one operation thus,

THEOR. *As the difference of the tangents of the complements of the arches cut in either station, is to the Radius; So is the distance betweene the stations, to the altitude.*

I 3

Because

Because accordingly as was before shewed, the tangent of the complement of $28^{\circ}, 7'$ is 18715 : and the tangent of the complement of $21^{\circ}, 58'$ is 24792 : whose difference is 6077. the proportions will in the line of Numbers be thus

$$\bullet \quad 6077 . 10000 :: 76 . 125 .$$

And these Rules may be also applyed to find out the distances of objects.

Example V. To find the declination of the Sunne the ninth day of May.

Because upon the ninth day of May the place of the Sunne is in $\circ 29$: which is 59 degrees distant from the next *Æquinoctial* point. Say in the line of Sines

$$\text{Radius} . \text{ sine } 59^{\circ} :: \text{ sine } 23^{\circ}, 30' . \text{ sine } 19^{\circ}, 59' .$$

And so much is the declination sought for.

If the distance of the Sunne from the next *Æquinoctial* point exceed not degrees $2^{\circ}, 30'$. Breake that arch into minutes, or decimal parts of a degree : and by the lines of Sines and numbers say

*As the Radius is
to the Sine of $23^{\circ}, 30'$;
So is the distance (of the Sunne from the next
Æquinoctial point) in minutes, or Decimals,
to the declination in minutes, or Decimals.*

As if the declination of the Sunne being in $\pi 27^{\circ}, 45'$ be required : the distance of it from the next *Æquinoctial* point is $2^{\circ}, 15'$ that is minutes 135, say therefore

Rad

Rad : sine $23^{\circ}, 30'$:: $135'$. $53\frac{1}{2}'$.

which is the declination of the Sunne in that place.

Example VI. To find the right ascension of the Sunne upon the ninth of May.

Because upon the ninth of May the Sunne is 59 degr : distant from the next *Æquinoctiall* point : say in the line of Sines on the Transversarie, and the line of tangents on the Staffe

Rad . sin : compl : $23^{\circ}, 30'$:: tan : 59° . tan : $56^{\circ}, 46'$.

which is the Sunnes right ascension upon the same day.

Or else (because the Radius is the meane proportionall betweene the tangent of an arch and its complement) the same proportion might have beene thus set downe.

t : com : 59° . Rad :: sin : com : $23^{\circ}, 30'$. t : $56^{\circ}, 46'$.

In which manner of propofure happening onely when there is in the proportion the Radius and two tangents, because the two homogenes of the one kind are both extreame termes, and the two homogenes of the other kind are both middle termes : the tangent is to be turned into the tangent of the complement : and must change places with the Radius. As by comparing the two former proportions doth plainly appeare.

Because that the greatest difficultie of working by these Rulers falleth out in the tangents, when the arches are in the second mediety of the Quadrant, it will bee convenient

convenient to set downe *some cases wherein the worke differeth from the ordinary manner.*

Case I. If the foure proportionals being all tangents, the arches of two of the termes given exceed 45 deg: and the arch of the third be lesse then 45 deg: as in this Example

$$\tan : 56^{\circ} \cdot \tan : 31^{\circ} :: \tan : 79^{\circ} \cdot \tan : 64^{\circ}, 24' :$$

here the tangent of 31° on the Transversarie being applied to the tangent of 56° on the Staffe, the tangent of 79° on the Staffe will outreach the Radius or end of the Transversarie. Wherefore to find out the fourth proportional, marke what point of the Staffe, the line of the Radius on the Transversarie doth touch, and to it (turning the Transversarie) set the other end of the line of the Radius, and so shall the tangent 79° in the Staffe give you tangent $64^{\circ}, 24'$ in the Transversarie.

Case II. If the foure proportionals being all tangents, the arches of the three termes given exceed 45 deg: as in this Example

$$\tan : 79^{\circ} \cdot \tan : 56^{\circ} :: \tan : 64^{\circ}, 24' \cdot \tan : 31^{\circ} .$$

turne the Transversarie, and set the tangent of 56° therein to tangent 79° on the Staffe: and because the Radius or end of the Transversarie reacheth not to the tangent $64^{\circ}, 24'$ on the Staffe: to find out the fourth proportional, marke what point of the Staffe the line of the Radius of the Transversarie doth touch, and to it (turning the Transversarie) set the other end of the line of the Radius, and so the tangent $64^{\circ}, 24'$ in the Staffe, will give you tangent 31° in the Transversarie.

These

These two Cases, being nothing else but a supplying of the shortness of the Transversarie, may serve as a rule, and direction for all other workes of the same kind.

Concerning the manner of working by *Quadrats* and *Cubes* upon the line of Numbers. And of *duplicated* and *triplicated* proportions.

The difference of a Quadrat from a Quadrat is double the difference between their sides.

And the difference of a Cube from a Cube is triple the difference between their sides.

Example II, chap: 6, part I. How many acres of Wood-land measured with a Perch of 18 feet, are there in 73 acres of Champane-land measured with a Perch of 16½ feet?

The measures given, 18, 16½ being reduced into the least termes, are as 12 to 11, and the proportion is reciprocal. Say therefore,

$$Q: 12, Q: 11 :: 73 . 61\frac{3}{4}$$

Which is thus wrought: In the line of Numbers apply 11 on the Staffe, to 12 on the Transversarie, then shall 73 on the Transversarie give 67 — on the Staffe: which 67 — being reckoned on the Transversarie (the Rulers standing as they did) shall on the Staffe give 61¼ the number of acres in Wood-land measure.

Example III, chap 6, part 1. If pounds 0143 of gun-powder suffice to charge a Gunne whereof the concave Diameter is yaches 1½: how many pounds of powder

B

will

will suffice to charge a Gunne whose concave Diameter is ynches 7?

The capacities are one to the other as the Cubes of the Diameters. And the proportion is direct. Say therefore

$$\bullet \quad C: 115 \cdot C: 7 :: 0143 \cdot 4317$$

Which is thus wrought: In the lines of Numbers apply 7 on the Staffe, unto 115 on the Transversarie, then shall 0143 on the Transversarie give 2101— on the Staff: which 2101— being reckoned on the Transversarie (the Rulers standing as they did) shall on the Staff: give 91333: and againe the same 91333 being reckoned on the Transversarie shall on the Staffe give 4317 the quantity of pounds of powder sufficing.

Example in 46 pag. of Navigation. A ship beginning her course at the Latitude of deg: 38², saileth upon the *W b N* Rumbe, unto the Latitude of deg: 50⁵: how many degrees of Longitude hath it varied in that course?

Here the angle of Inclination of the *W b N* Rumbe with the Meridian is 78², 45', the tangent whereof is 501734. And by the *double divisions on the fourth side of the Staffe*, the Summe of the Secants for the Latitude of 50⁵ is 581991: and the summe of the Secants for the Latitude of 38² is 411392: the difference of which is 171299; the summe of the Secants of the parallels betweene those two Latitudes. Say therefore.

$$\text{Rad} \cdot \text{tang} : 78^{\circ}, 45' :: 171299 \cdot 861768$$

which is the difference of Longitude betweene the Meridians of the two places.

But because this question is of excellent and very frequent

quent use, it will not be amisse to set downe at large the manner of working this Example upon the Rulers.

Looke the two Latitudes $50^{\circ} 15'$, and $38^{\circ} 12'$ given, in the line of Latitudes or eleuations of the Pole on the fourth side of the Staffe: and either marke what number each of them sheweth in the line of *Equall parts* there, which you shall find to be $58^{\circ} 49'$, and $47^{\circ} 13'$, the difference of which is $17^{\circ} 36'$, as was before said: or else more easily, set one foot of your Compasses on one of the Latitudes given, and open the other foot to the other Latitude given: then keeping that aperture, set one of the feet in the beginning of that line of *Equall parts*, and the other foot shall upon the same line shew the difference of Secants betweene the said two Latitudes given, that is $17^{\circ} 36'$.

Then in working the Proportion; because the angle of inclination of the Rumb $78^{\circ} 45'$ is more then 45 deg: turne that edge of the Transversarie on which the tangents of arches above 45 are, toward the Staffe in your right hand: and to the line of the Radius apply $17^{\circ} 36'$ sought out on the line of Numbers on the Staffe: and so shall tang: $78^{\circ} 45'$ on the Transversarie: shew 86197 — on the Staffe.

The Vse of the Crosse-Staffe.

For the more ready use of the Crosse-staff, you are to remember that the degrees serving for the Crosse-staff are placed both on the Staffe and Transversarie, on the same side on which the line of Sines is. And that in framing thereof the Transversarie is to be set in the Socket so that it may stand on the right hand of the Staffe.

The degrees on the Transversarie are only the first 30. and serve to shew an angle not exceeding 30 degrees.

Yet it would not be unusefull if both the Transversary and Staffe were made somewhat longer than the Transversarie might containe 5 deg: after 30; and the Staffe 5 degrees before 30.

*To find an angle lesse then 30 degrees:
between any two objects.*

Place the Socket at 30 deg: on the Staffe; and skrew it fast there: then setting the end of the Staffe to your eye, draw the Transversarie up and downe through the Socket, till you may see with your eye the two objects upon the two sights of your Crosse-staffe: and so shall the degrees cut on the Transversarie shew you the angle of their distance, if it be not above 30 degrees.

*To find an angle greater then 30 degrees,
between any two objects.*

Place the Socket at 30 degrees of the Transversarie, and skrew it fast there: then setting the end of the Staffe to your eye, draw the Socket up and downe along the Staffe till you may see with your eye the two objects upon the two sights of your Crosse-staffe: and so shall the degrees cut on the Staffe, shew the angle of their distance, if it be above 30 degrees.

And thus much, together with that which hath been before taught in *Example III*: will bee sufficient for the Use of the Crosse-staffe: especially seeing so many men have already writ ten upon this Argument.

Soli Deo gloria.

FINIS.

The Translator to the Reader.

Gentle Reader, by reason of my absence, while this Booke was in the Presse, it is no mervaille though some faults have escaped, which you will be pleased to amend thus.

Pag. 3, lin. 1, the third circle p. 8, lin. ult. so $\frac{11}{12}$ is 0.75 ,
pag. 14, lin. 14, 2. 0.413927 pag. 15, lin. 1, the first
terme of a progression p. 16, lin. 24, 108.334 ; pag. 17,
lin. 17, the antecedent arme lin. 28, 4 chap. pag. 18,
lin. 19, terme given from pag. 19, lin. 11, in the first
circle pag. 20, lin. 19, lye hid. As in this lin. 20,
D . rat. $\text{mult}^a - 1$ in R :: a . Z .
lin. 28, and Rat. mult^a in R in a — R in a,
lin. ult. and Rat. mult^a in R — R, in a,
pag. 21, lin. 1, and Rat mult^a in a — a, in R,

And also in the Equations pag. 21, 24, 26, which have
a magnitude aqmall to a fraction: the same magnitude to-
gether with the note of aquality, ought to be set right against
the line that is betweene the Numerator and Denominator
of the fraction, as in these, $\frac{\text{Rat. mult}^a - 1 \text{ in R in } a}{D} = Z$.

And $\frac{ZD}{a} = \text{Rat. mult}^a \text{ in R} - R$. And so of the rest.

pag. 24, lin. 25, $\frac{\text{Rat. mult}^a - 1 \text{ in R in } a}{\text{Rat. mult}^a \text{ in D}}$

pag. 25, lin. 20, arme at 71.382 :

lin. 23, (for it is Rat. $\text{mult}^a - 1$ in R in a)

pag. 26, lin. 16. Ratiocination pag. 29, lin. 29, number
of figures pag. 35, lin. 5, 61.113 pag. 36, lin. 17,
 437 . 17.48 . lin. 24, :: 17.48 . 3.264 pag. 37,
lin. 11, 3.1416 , pag. 39, lin. 15, 339.2928 pag. 41, lin. 19,
or as 1 is to 1.0472 : pag. 44, lin. 8, is a rooffe lin. 26,
thereof pag. 45, lin. 10, feet 529.175 . pag. 46, lin. 3,
more sides then foure pag. 53, lin. 10, Cylindrical vessel.

pag. 53, lin. 18, if false, why lin. 20, error? pag. 57,
 lin. 14, common opinion is, that at London a Cylindrical
 lin. 28, 16, 5 pag. 74, lin. 28, the Summe, pag. 78, lin. 6,
 third houses lin. 28, Adde 90 degrees pag. 79, lin. 22,
 and the 90th degree pag. 82, lin. 5, 26 pag. 94, lin. 21,
 a circle, or 90 degrees. pag. 95, lin. 34, angle D be ob-
 tuse, pag. 96, lin. 4, signe + lin. 31, $\sqrt{q} : Z + X$: pag. 100,
 lin. 3, and then the side DC In the VIII diagramme of
 right-lined Triangles the letter A is wanting at the perpendi-
 culer. And in the VI the angle B ought to have been mar-
 ked with a little line. pag. 113, lin. 7, the delineation
 pag. 137, lin. 1, the sunne goeth not under pag. 131,
 lin. 19, in the paper pag. 132, lin. 10, 10 the tangent of
 the arch. pag. 134, lin. ult. North or South direct in-
 clining: pag. 135, lin. 1, North or South direct re-
 clining. lin. 8, either face of the Plaine looketh: p. 143,
 lin. 3, In North reclining and South inclining pag. 144,
 lin. 19, instrument through the Pole of the *Æquinoctial*,
 is one of these three: pag. 152, lin. 30, North dial de-
 clining Eastward 35 degrees

In the Additament of Navigation.

pag. 2, lin. 11, for value read value pag. 6, lin. 9, & 12,
 for signes read fines pag. 39, lin. 20, 21, 24, for 45 read 48
 lin. 20, for an halfe read eight thousand parts &
 lin. 25, for min: 27 read min: 288 pag. 45, lin. 20
 pag. 47, lin. 9, & 28, pag. 48, lin. 17 & 21, for 87, 927:
 read 86, 968 pag. 47, lin. ult. for 205734, read 502734.

pag. 28, lin. 8, 216000F
 349800G

and the other arme at $131^{\circ}53$ in the *fifth circle*. Then remove the arme that stood at $131^{\circ}53$, unto 567 degr: the greater *Latitude*, and the other arme, at the same opening shall cut 481 degr: which is the lesser *Latitude* sought for.

And if the two *Latitudes* be in the severall Hemispheres, that is one *Northerne* and the other *Southerne*, the manner of working differeth in effect but little from the former. As if the summe of the *Secants* betweene these two heights of the Pole, viz. 615 on the North side of the *Aequinoctiall*, and 1314 on the South side bee desired. Set one arme of the Index on the line of the Radius, and the other arme on either of the *Latitudes* given, suppose on 615 . Then bring that arme on 615 unto the line of the Radius: and where the other arme, at that opening chanceth to light, there hold it fast: and open the arme that standeth on the line of the Radius, unto the other *Latitude* 1314 . Afterward bring the arme that stood on the former *Latitude* 615 unto the line of the Radius, and the other arme, at the same opening, shall in the *fifth circle* cut 20937 , the summe of the *secants* sought for.

Lastly, the summe of all the *Secants* betweene two *Latitudes*, of which one is on the North side of the *Aequinoctiall*, and the other on the South side, being given; together with one of the *Latitudes*, to find the other *Latitude*: As if the summe of the *Secants* bee 20937 and the *Latitude* degr: 615 . Set one of the armes of the Index at the line of the Radius: & open the other arme unto 20937 in the *fifth circle*: and keeping the same aperture, bring this latter arme unto the *Latit*: 615 : and where the former arme shall light, there hold it fast, drawing in the latter arme to the line of the Radius. Lastly with this new opening bring the other arme to the line of the radius: and so shall you find 1314 , the other *Latitude* sought for.

Or.

Or else peradventure you may more easily find out the summe of the Secants betweene any two Latitudes given, thus: Set the edge of the Index upon one of the Latitudes: and looke what division it cutteth in the fifth circle: keepe it in mind. Againe, set the edge of the Index upon the other of the Latitudes: and looke what division it cutteth in the fifth circle: keepe that in mind also. These two numbers kept in mind are the summes of the Secants for the two Latitudes given: And are to bee subduelled one out of the other, if the Latitudes are both in the same Hemisphere: or else to be added together, if the Latitudes are in diverse Hemispheres.

Also in like manner, The summe of the Secants and one of the Latitudes being given, you may find out the other Latitude, thus: Set the edge of the Index upon the Latitude given; and looke what division it cutteth in the fifth circle. To this number adde the summe of the Secants, if the lesser of the two Latitudes be given: Or else out of it subduelt the summe of the Secants, if the greater of the two Latitudes be given. But if the two Latitudes are in the contrary Hemispheres, the number found in the fifth circle is to be subduelled out of the summe of the Secants: And so shall you have the other Latitude.

CHAP.

